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John F. Wallace, President for 1896.

Journal of the Western Society of Engineers.

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VOL. I. JANUARY, 1896. No. 1.

I.

NOTES ON DRY DOCKS OF THE GREAT LAKES.

By A. V. POWELL, M. W. S. E.,

Read Sept. 24th, 1895.

The dry dock can be counted as one among the many aids to commerce that have been developed during tnis century. The early navigators hauled their boats on shore to repair them; and a modification of this method is still in use in the appliance called the ship railroad, and we usually find that wherever there is to-day a dry dock, its site has been previously used as the location for a ship-railway. The dry dock, as we now know it, seems to have been developed from the "grave;" in England to-day it is known as a graving dock. Where the tides were available, the vessels were beached at high tide, repaired while the tide was out, and floated at the next tide. This method was followed by the excavation of a bed in which to place the ship to be repaired, called a "grave." After the vessel was in place and the tide ran out, the "grave" was closed at the outer end by an embankment thrown across it; this allowed continuous work on repairs. This method is still in use. The "Petrel," of the United States navy, was docked at New Chwang, Manchooria, China, in this way during the winter of 1894-5. The "Great Eastern" was docked at Milford Haven in this way. The Chinese used the method four hundred years ago. Where the tides raised to a sufficient height, docks were constructed so that ships could be floated into them at high water, and the receding tide left the dock dry. No gate was used, the only requisite being a sufficient foundation to support the weight of the ship and provision made for shoring. The introduction of a movable gate to shut out the water from the tidal docks was the next step in advance, the gates being substantially the

same as those which are now in use in canal locks, i. e.—swinging gates. The floating gate or caisson was invented by Sir Samuel Benthan and was first used in a tidal dock at Portsmouth (England) navy yard.

Finally, by the introduction of steam pumping machinery for removing the water from the dock, we have the dry dock of to-day.

The first floating dock is believed to have been constructed about the time of Peter the Great; a North Country captain having floated his ship into an old hulk, pumped the water out and made his repairs. The name of the hulk was "Camel," and this name the English still give to the pontoons that are used for raising ships. The floating dock was built in England about 1785. An American invention, called a screw dock, was built at New York in 1776. This dock consisted of a cradle into which the ship floated and the cradle and ship were then raised by screws attached to the cradle and bearing upon the tops of piles driven on each side of the structure. The dry dock at the Brooklyn navy yard, the largest in this country at the time it was constructed, was commenced in 1841 and completed in 1851, at the cost of about two and one-fourth million dollars. This dock was constructed of granite on a foundation of piles and concrete. The first dock constructed on the American side of the great lakes was built at Buffalo. In 1836 there was a ship railway at Ohio street, Buffalo, built by Bidwell & Banty. A capstan turned by horses was the power used. In the same city, about the same time, another ship railway was constructed, where the Union dry dock is now located, and operated by steam power. This last was replaced in 1838 by a dry dock large enough to dock any vessel then navigating the lakes; the depth of water on the sill was 8 feet. This dock was enlarged in 1844 and again in 1848 in order to accommodate vessels of increased size.

A ship railway was built in Cleveland, in 1844, by Tisdale & Johnson, a floating dock in 1847, and in 1870 a dry dock was built by Stevens & Presley. This dock was 250 feet long on the blocks, with 10½ feet of water on the sill. In 1876 this dock was lengthened to 290 feet, and in 1892 the old dock was taken out and the present Cleveland Dry Dock Company's dock built. This dock is 360 feet in length and has 20 feet of water on the sill. In 1888 the Ship Owners Dry Dock Company of Cleveland was organized. The same year they built a dry dock at the head of the old river bed, 340 feet on the blocks with 16 feet of water on the sill. This last dock the company are now lengthening to 440 feet on the blocks, the depth of the entrance remaining the same. The company also own and operate a dock built in 1890, having an effective length of 300 feet, with 13½ feet of water on the sill. The same pumping plant discharges the water from both these docks.

At Detroit, in 1851, Lew, John and Hiram Ives built a dock at a point now known as the foot of Swain avenue. I have been unable to get particulars as to its size. The second and third docks at Detroit were constructed by John Clark, in 1855 and 1857, respectively. These last two docks are still in use. Campbell & Wolven

built a dock in 1859; Campbell & Owen another in 1866. This last-mentioned dock was removed and the dock now owned and operated by the Detroit Dry Dock Company was built on its site in 1892.

Port Huron has three docks, the largest, owned by Dunford & Alverson, was built in 1891. At Bay City, Mich., Church & Co. converted the hulk of the once famous passenger steamer "Western World" into a dry dock in 1871. This dock was operated until 1877, when a ground dry dock was constructed; it having been found that the clay upon which the old hulk rested was firm enough to withstand the pressure of the water, a slip was dug 250 feet long and a gate-way constructed, but no sides or foundation was put in. The only dry dock on the American side of Lake Ontario is located at Oswego. This dock was built in 1865 by George Goble. It is 175 feet long and has 10 feet of water over the sill.

The dock of the American Steel Barge Company, at West Superior, Wis., was built in 1891, and is the only one on Lake Superior. It is the longest dock on the lakes, being 500 feet on the blocks.

At Chicago, Conner in 1848 had a set of ways at Van Buren street, where vessels could be pulled up.

In 1848-9 Doolittle & Miller built boxes to raise boats of 300 to 400 tons register.

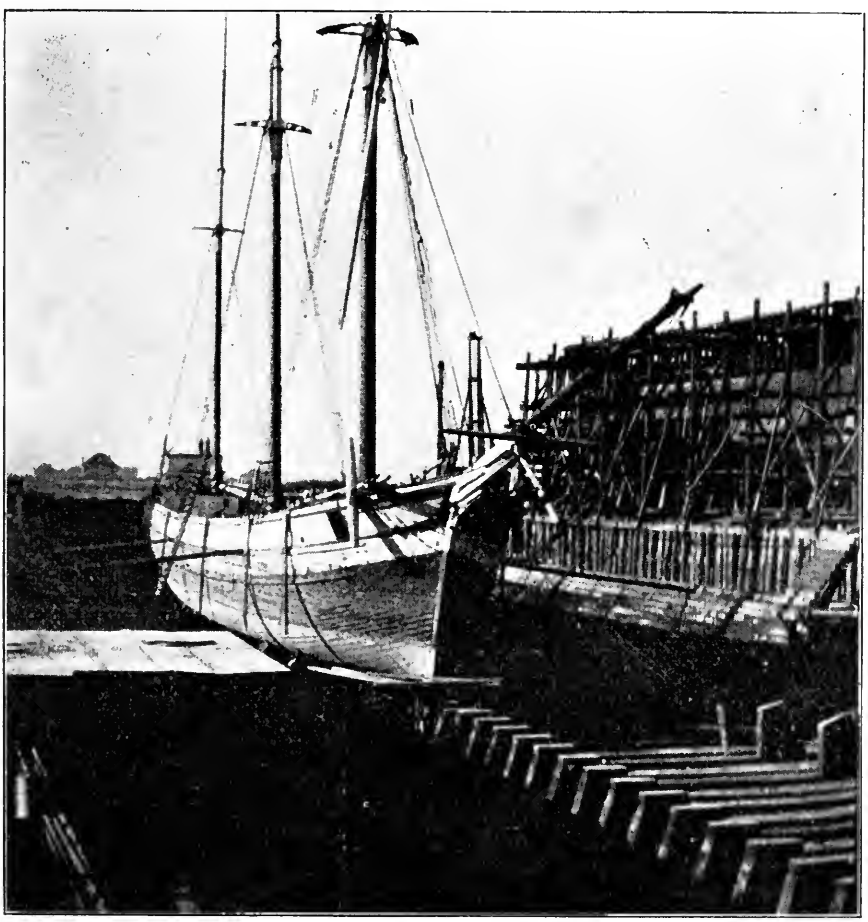


FIG. 1.

The first dry dock in Chicago was built in 1854-5. George Wicks started the work in 1854; he sold his interest to Doolittle & Miller, and the dock was completed by them in 1855. This dock is still in use. It is known as Miller Bros.' Dock No. 1, and is located at North Halsted street bridge. Length, 275 feet. Water on sill, 8 feet. Miller Bros., successors to Doolittle & Miller, constructed a dock in 1871-2, located alongside their No. 1 dock. This dock is 310 feet in length and will admit vessels drawing 14 feet of water. A dock was built at Polk street in 1863, 250 feet long—lengthened in 1870 to 305 feet and abandoned and filled up about 1888. E. M. Doolittle constructed a dock at an early day on the West Side. This dock, now abandoned, was 235 feet long, and would admit boats drawing 12 feet.

Dry Dock of the Chicago Shipbuilding Company (Fig. 1).

The last dry dock completed on the great lakes was built by the Chicago Ship Building Company at South Chicago, during the summer of 1894, from plans by and under the supervision of the writer. This dock is located on the east side of the river, about one mile from Lake Michigan. The natural surface of the ground at the site of the dock is about 3 feet above Chicago datum, and the soil to a depth of 14 feet below the Chicago datum is sand, underlaid with clay, extending to the rock, which, at this point, is found about 60 feet below datum. Before the design of the dock was settled borings were taken over the ground upon which it was located. These borings were made 25 feet apart, at right angles to the line of the proposed dock and 50 feet apart in the direction of the axis of the dock. They were made by driving casing down to the clay, the sand being taken out of the pipe with a sand pump, then with a screw auger we bored to a depth of 45 feet. A line of borings, extending to a depth of 60 feet below datum, was taken at the entrance. All the borings showed uniform material over the entire area. The clay was comparatively soft at the top, becoming harder as the depth increased, until the lower stratum was reached, which consisted of hard pan, an admixture of clay and gravel. No boulders were encountered in the borings, although several stones of considerable size were dredged up when the pit was excavated. On the site of the dry dock a slip was built in 1890. The sides of the slip were docked with the ordinary sheet-pile dock, piles spaced 2½ feet centers, 25 feet in length. The sheeting was of oak, 3 inches thick, 18 feet in length, and penetrated the clay from 1 to 2 feet. The sheeting was lined with 1-inch pine boards covering the entire surface and extending to the clay. The front of the dock was held in place by anchor rods 1¼ inches in diameter, spaced 5 feet, extending to a line of anchor piles driven 30 feet from and parallel to the face of the dock. The anchor piles were 20 feet in length and driven 5 feet apart, center to center. At the time the docking was put in, the slip was dredged to a depth of 12 feet below Chicago datum.

The first work done on the construction of the dry dock was to dredge the slip to a depth of 25 feet below Chicago datum. The material was removed as close to the line of the dock as it could be with an ordinary dipper dredge and was left in the shape in which you see it on the screen. (Fig. 2.) After the dredging had been done a coffer-dam was constructed across the mouth of the slip, consisting of two parallel rows of 30-foot piles, 16 feet apart, the piles in the inner row being driven 4 feet, center to center, and those in the outer row 6 feet, center to center. Wales were put in the inner and outer side of these lines of piling, and a double row of 3-inch pine sheeting, 24 feet in length, driven on either side. These two rows were secured together by bolts $1\frac{1}{2}$ inches in diameter, spaced 4 feet apart. The

FIG. 2.

coffer-dam was filled with clay and mud dredged from the river, no effort being made to select the material put in the dam. (Fig. 3.) At the northerly end of the dam, where it connected with the dock, was a bank of sand extending to within 6 feet of the surface of the water and back into the dam about 10 feet, the water at that point being about 14 feet in depth. This sand was allowed to remain in the coffer-dam. After the dam was completed, the water was pumped from the slip by a centrifugal pump placed on a scow anchored in the river opposite the dam. Everything held in place until the surface of the water in the pit was lowered to 10 feet below datum, when a leak started at the point in the dam where the sand had been allowed to remain, and, while no damage was done to the work, the leak increased to such an extent that the pumps were unable to control it, and in the course of the next twelve hours the slip filled

Fig. 3.

with water, carrying with it all the sand that was allowed to remain in the coffer-dam. After the slip had filled we re-sheeted that end of the dam to make sure of our connection, re-filling the part washed out with clay, and from that time until the work was completed we had no further trouble. After stopping the leak we again started the pumps and cleared the pit in three days.

Now let me state, that the sheet pile dock, which I have before described (having a total length of 1,000 feet), sustained the pressure of 20 feet of earth (18 feet of sand and 2 feet of clay) for a period of three months, or, until the sides of the dry dock were put in, without yielding at any point. After the pit was pumped the foundation piles were driven. These piles were driven in rows across the dock, the rows being 5 feet apart, and the piles spaced from 4 feet apart in the center to 5 feet at the sides in each row. Under the portal the piles were driven to support the cribs and across the portal, as shown in the drawings. (Fig. 9.) The foundation piles furnished were a uniform length of 20 feet, but could not be driven to their full depth on account of the hardness of the material, the average penetration being $17\frac{1}{2}$ feet. The drop hammer used for driving the foundations weighed 3,000 pounds, and the piles were given a finishing blow of 30 feet.

Sheet Piling.

A line of sheeting extends entirely around the dry dock. It is placed from 30 to 60 feet from the sides of the dock. The sheet-

ing is practically water tight. All of the water which came into the pit through the sheeting, coffer-dam, and from springs in the bottom of the dock, was discharged with a No. 3 Nye pump, working six hours per day. Across the portal there are two lines of sheeting corresponding to the inner and outer positions of the sill. This sheeting is 12 feet in length and is driven to its full depth. Along the sides of the dock 30-foot piles were driven 5 feet centers to which the batter braces or altar carriers are bolted.

Entrance to Dock.

The cribs and floor of the portal rest on piles driven as shown in the plans. After the piles were driven all loose material was removed and the space to the level of the bottom of the apron was filled with concrete, thoroughly tamped into place. The apron of the dock is constructed of 12x12 timber, and is bolted to the foundation piles by strap bolts extending 3 feet down the sides of the piles and up through the apron. This apron is 40 feet in length by 50 feet in width, the width of the dock entrance. The cribs that take the thrust of the gate are built of 12x12 timber, each course being

Fig. 4. Crib at Entrance of Dock.

drift-bolted every 3 feet. The drift bolts are one inch square and 30 inches long. The sills are made of two pieces of 12x14 oak, set on edge and rabeted into the apron and cribs 2 inches. They are held in place by bolts extending down through the apron and attached to the foundation piles, and to the cribs by bolts extending through the cribs. The dock has two sills. They are 15 feet apart

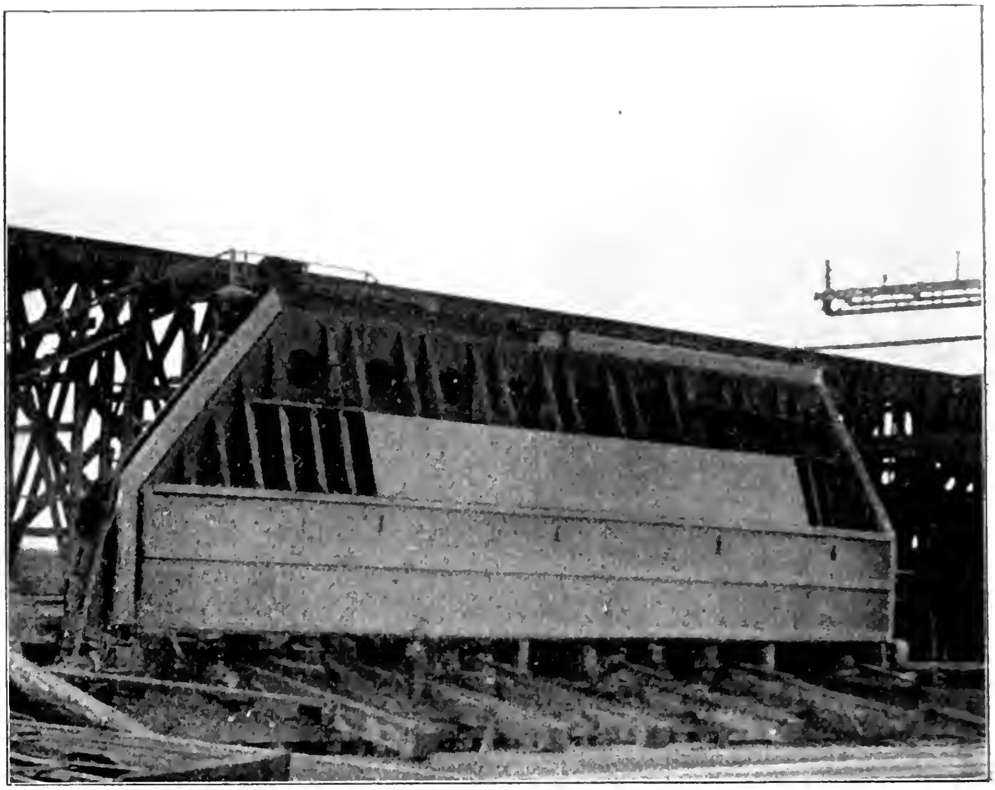


FIG. 5.

FIG. 6. SHOWING GENERAL CONSTRUCTION.

The caisson is constructed of steel. (Fig. 5.) It is 72 feet in length on deck—52 feet on bottom—13 feet in breadth at the center, and 24 feet in depth. Its general appearance is shown in the cut; it being understood that it is shown as it was built, deck down. (It turned to its proper position when launched.) The caisson is provided with nine gate valves 30 inches in diameter for filling the dock, and two 8-inch gate valves for filling and emptying the structure itself. The filling gates have sliding stems, and are operated by ratchets placed on the main deck.

Body of the Dock.

The floor timbers are 14x14 inches and rest upon and are drift-bolted to the foundation piles. The planking is cut in between the floor timbers. It rests on ribbons spiked to the main timbers. No attempt has been made to secure a water-tight floor; in fact, the planks are separated so as to allow the water to run through it and into the drainage culvert.

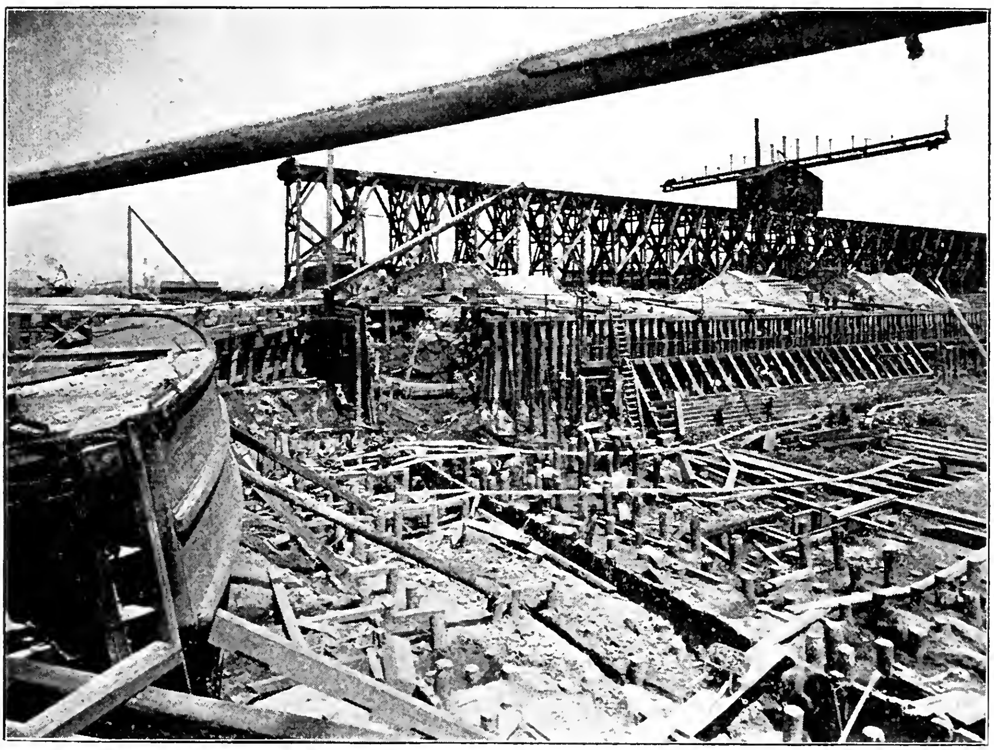


Fig. 7. Showing Sheeting and Foundation Piles under Entrance.

The altar carriers are stepped into the floor timbers and drift-bolted to them. At the top they rest upon and are fastened to a wale which, in turn, is bolted to the piles of the original sheet-pile dock of the slip. These carriers are also fastened near the center to piles driven about 5 feet in front of the sides of the dock. The altars are sawed to give a raise of 10 inches and a tread of 6½ inches. The altars are spiked to each altar carrier with two 10-inch by 9-16 boat spikes. The space behind the altars is filled with clay tamped to make a puddle. A puddle wall 2 feet thick was also put in, extend-

ing entirely around the outside of the dock. This puddle wall stands on the clay in place and the top of it is 2 feet above Chicago datum.

Drainage Culverts and Pump Well.

The pump well is located at the south side of the dock near the entrance. It is 12x26 feet inside, constructed of 12x12 timber drift-bolted together. The bottom of the well is made of grillage of 12x12 timber and rests upon the clay. The bottom of the pump well is 10 feet below the floor of the dock, and connection to the dock is made through a semi-circular brick culvert, extending beyond the side wall of the dock and with an open culvert from there to the center of the dock. Along the center of the dock is a drain 5 feet in width from the head of the dock to the drainage culvert. The drain is 5 feet deep at the drainage culvert and 1 foot deep at the head of the dock.

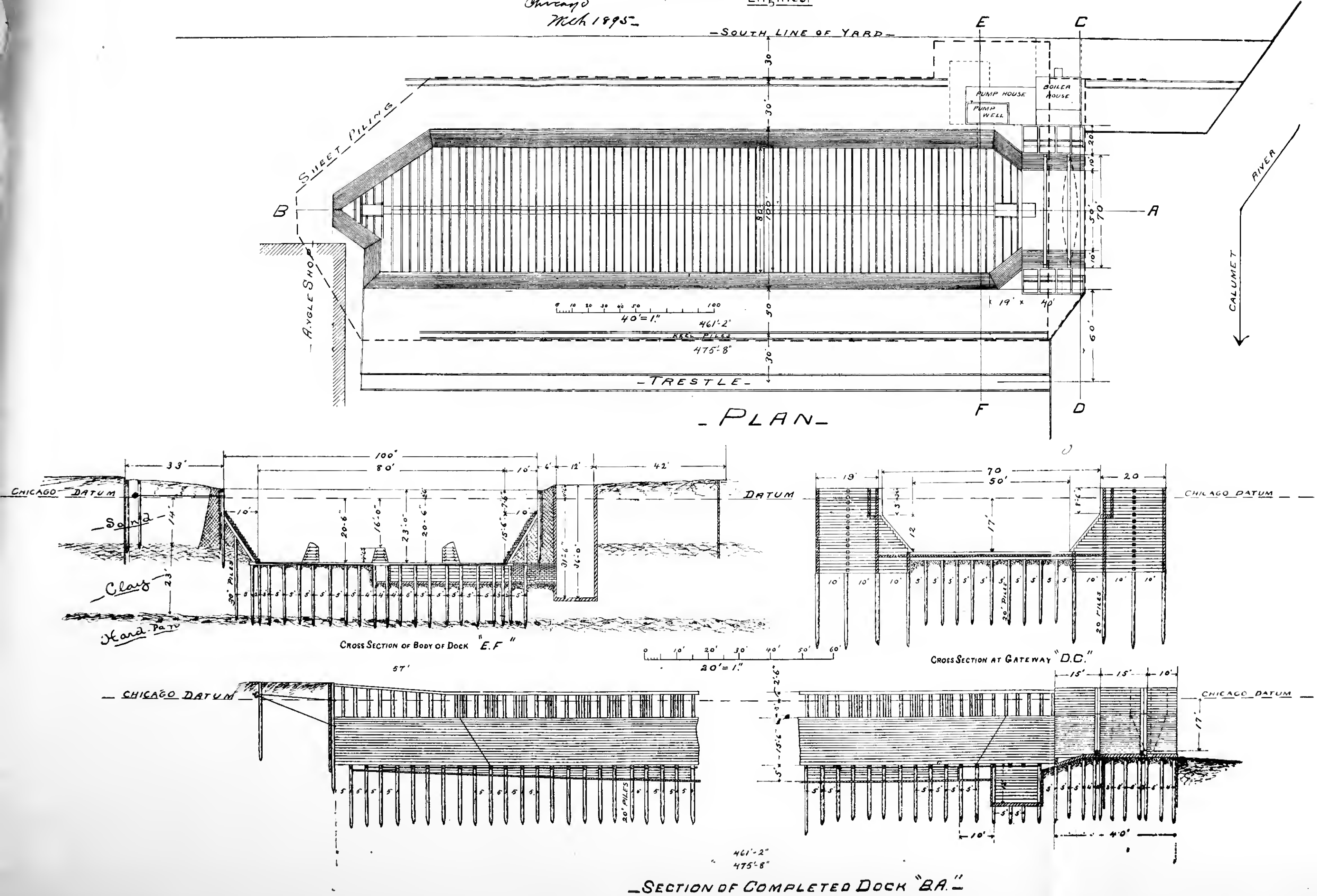
Pumping Plant.

The pumping plant built by Southwark Foundry and Machine Company consists of two vertical centrifugal pumps placed in the bottom of the pump well. These pumps discharge through pipes 30 inches in diameter and have a rated capacity of 25,000 gallons per minute each. The pumps are driven by two vertical high-pressure engines, 18 inches in diameter by 18 inches stroke. The pumps are run

Fig. 8. Testing Caisson before Removal of Coffer Dam.

Western Society of Engineers.
Vol. 1, No. 1. Figure 9.
Powell—Notes on Dry Docks.

CHICAGO SHIP BUILDING COMPANY'S
DRY DOCK
102nd ST. & CALUMET RIVER SOUTH CHICAGO ILL
A.V. Powell
Engineer
Chicago
Mch 1895



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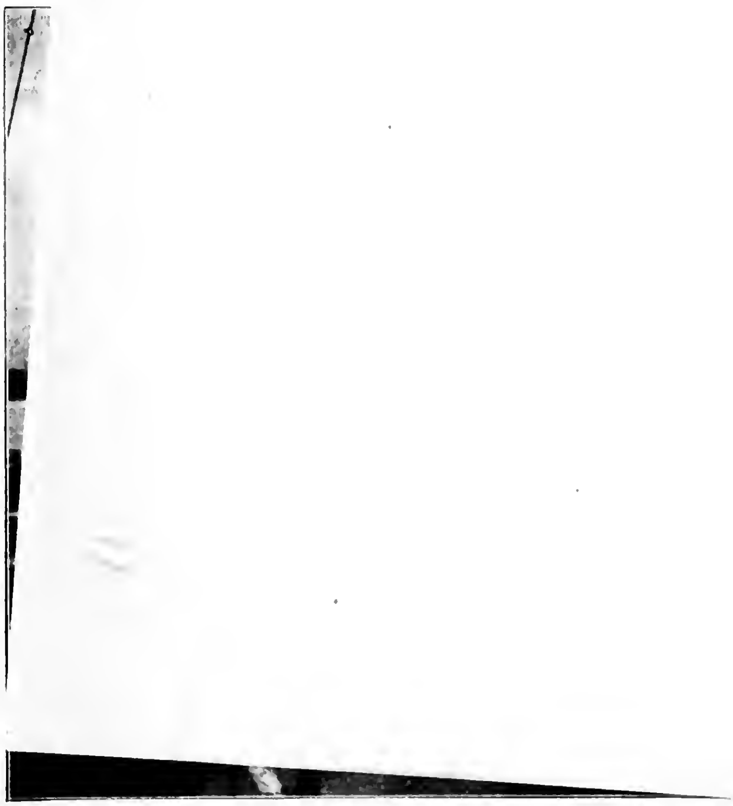


Fig. 8. Testing Caisson before Removal of Coffer Dam.

at the speed of about 160 revolutions per minute. The steam plant consists of four horizontal tubular boilers, each 60 inches in diameter and 16 feet in length. Oil is used for fuel.

With all the valves in the caisson open the dock fills in 20 minutes. It requires two hours to pump the dock when there is no boat in it, the volume discharged being 7,000,000 gallons.

The dry dock has been in successful operation for ten months.

The following are the general dimensions of the dock:

	Feet.	Inches.
Total length—face of crib to head of dock..........	475	8
Clear length—inside of gate to head of dock........	461	2
Width of body at top..............................	100	0
Width of body at floor............................	80	0
Total depth of dock...............................	23	0
Depth of dock below datum.........................	20	6
Depth of water over keel blocks...................	16	0
Depth of water over sill..........................	17	0
Width of entrance on sill.........................	50	0
Width of entrance 12 feet above sill..............	70	0
Width of entrance at top..........................	70	0
Height of the keel blocks.........................	4	6

Note.—The depths of water as given in the above table are depths below Chicago datum, which is one foot below U. S. Government datum.

II.

ORIENTAL RAILWAYS.

By Clement F. Street.

Read December 4th, 1895.

It was my pleasure to be the engineer for the Commission on World's Transportation of the Field Columbian Museum, which was formed for the purpose of collecting information for the completion of the museum of the world's railways, which is a department in Field's Columbian Museum, located at Jackson Park, this city.

We left London on the 8th of last October, after having spent one month in that city making preparations for a tour through the East and in looking over the wonderful railway terminals of that city. The first country visited was Tunis, North Africa, and, from a tourist's point of view, the city of Tunis is one of the most interesting points we visited throughout our entire journey; but, from an engineering standpoint, there is not very much to be found in either the city or country. The railways of the country are three in number, but two of them are rather insignificant affairs and hardly more than suburban lines. The third is the Bone-Guelma Railway, which is a system of about 376 miles, having its eastern terminus in the city of Tunis and its western end connecting with the Paris, Lyons & Mediterranean Railway, which, together with the East Algerian Railway, form a continuous line between Tunis and Oran. All of these railways were built and are owned and operated by Frenchmen and subsidized by the French government for military purposes. One branch of the Bone-Guelma Railway, extending from Tunis to Bisert, has recently been completed and is intended almost solely for military purposes. There is an inland lake at Bisert about 15 miles long, varying from two to five miles in width, and having a depth of between 60 and 100 feet. This lake is separated from the Mediterranean by a narrow neck of sand and soft rock. A channel is being cut through this neck and when we were there some endless chain bucket dredges were at work excavating the sand, and I was told it cost about 20 cents per cubic yard to take it from the bed of the stream and spread it over a fill which was being made for building purposes.

The Bone-Guelma Railway, the Paris, Lyons & Mediterranean, and also the East Algerian, are similar in all respects. The gauge is 4′ 8½″, the ties are mostly of wood, although steel is being used experimentally, the rails are of the T pattern, the roadbed is kept in excellent shape, the ballast is usually of broken stone, and where fence is used at all it consists of a prickly pear hedge. Each switch has a disc signal set on top of a high iron post and operated by a lever on the base of the post. The bridges are stone arches and deck girders of steel, and there are numerous tunnels and retaining walls which are unusually fine pieces of cut stone masonry. The stations are neat and substantial looking structures of uniform design and

built of cement or concrete with stone facings and tile roofs. Wood of all kinds is very scarce in these countries and many peculiar and striking substitutes for it are seen on all sides.

From North Africa we went to Egypt, and there found one of the best and most complete railway systems it was our pleasure to inspect. The railway is owned by the government, but the general manager and locomotive superintendent are both Englishmen, and therefore the English style of equipment is used. The locomotive superintendent is Mr. F. R. Trevithick, a grandson of the Father of the Locomotive, and the engines he has designed and is operating would be a credit to any railway in the world. The chief engineer of the line is Mr. M. Nicour, a Frenchman, and while he may have had some engineering problems to solve in constructing the road along the Upper Nile, about Cairo the line is perfectly straight and on a dead level. Most of the line is laid with bull-head rails resting on cast-iron pot sleepers, but this practice is being abandoned in favor of pressed steel sleepers. All trains are operated under the manual block system, signals being given by semaphores at each station, both a home and distant signal being used.

The railway station at Cairo is a new building just completed, and is an exceedingly fine structure, both inside and out. In its interior finish it is rather exceptional, as I saw very few railway stations built by Englishmen where the interior finish was given much attention. The two upper floors of the building are used for offices and in them a large force of native clerks are kept at work. The

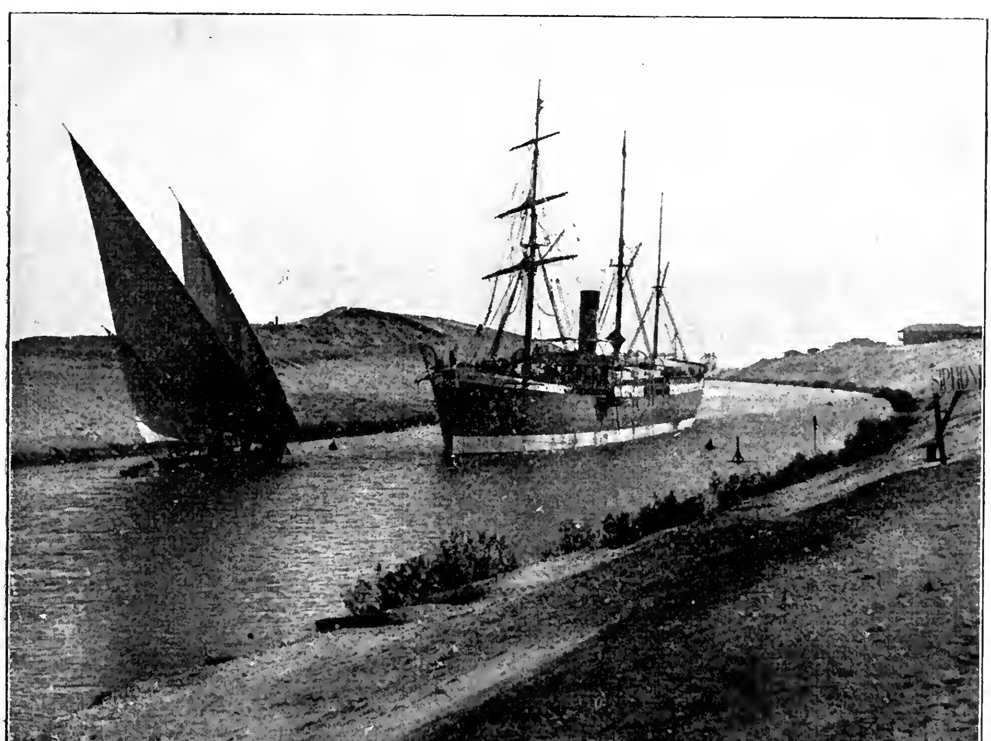


Fig. 10. Suez Canal—El Guirsh Curve.

heads of departments are all Europeans, but most of the employes in all departments are natives.

The camel is, of course, very common in Cairo, and while riding on the railway I counted a string of fifty-three, the nose of each one, excepting the leader, being attached by a cord to the tail of the camel ahead of him.

While in Egypt we visited the Suez Canal, and it is probably the most insignificant looking affair for the importance it really holds in the commerce of the world that there is in existence. The banks on both sides are nothing but sand piles, and extending back as far as the eye can reach in all directions there is nothing but a sandy desert, and I do not think it possible for any one who has never seen a sandy desert to form any conception of how utterly barren and desolate the surface of this earth can appear. The accompanying illustrations show typical views along the canal and also some of the excavating machinery which is constantly at work at many points. This work is done almost exclusively by endless-chain bucket dredges of the English pattern, and in practically all cases the spoil is carried by an elevator to a height sufficient to allow it to be discharged in a liquid state to a point outside the original bank. With this method there is no rehandling, although near the ports the spoil must be discharged into hopper bottom scows and towed out into the sea.

Fig. 11. Suez Canal—Conveyor Dredge.

From Suez we took a steamer to Colombo, Ceylon, and this country is, I think I can safely say, the most beautiful of any we visited, as flowers and all kinds of vegetation are probably found in

such profusion in no other country in the world. The railway belongs to the government, and consists of about 270 miles of 5′ 6″ gauge track, the main line of which extends from Colombo to Bandarawella, a distance of about 160 miles. Between Colombo and Pattipola, a distance of 139 miles, the rise is between 6,000 and 7,000 feet; the first 30 miles out of Colombo is very nearly level, and after passing over this section, which extends through a succession of rice fields and plantain groves, the base of the hills is reached, and from this on there is a succession of sharp curves, tunnels, bridges and heavy grades, surrounded by scenery of a grandeur not seen in many spots in the world. The prevailing grade is 1 in 44, the average speed of the train for the entire distance, including stops, is 14 miles per hour. The train that we went up on had some eight coaches, of the Bogie type, and was drawn by a ten-wheel engine which would weigh probably 130,000 pounds. At many points we crawled along at a speed so slow that we could have jumped off the train and run along by its side. It is not uncommon to find a curve of 5 chains radius on a grade of 1 in 25, which you know very well makes pretty heavy work for locomotives.

One of the most serious impediments in the way of good railroading in Ceylon is the heavy rainfall. We were shown one place where it was claimed 24 inches of rain had fallen in twenty-four hours, and in some parts of the island the yearly rainfall is upward of 300 inches. This rainfall makes it necessary to construct heavy retaining walls at all cuts or fills, and even with these it is sometimes impossible to hold the roadbed in proper condition. The bridges must be very substantial and are built with heavy stone abutments and central piers of wrought-iron cylinders filled with concrete, sunk to a solid foundation. The original method employed in the building of the abutments is quite interesting. The stones used are quarried in the country and worked up by the natives. They are most of them of pretty good size and elephants were used exclusively for handling and placing them. The method of working was to put an endless chain around the elephant's neck and a second chain around the stone to be moved. These chains were of such a length that when the elephant dropped his head the chains could be hooked together. After this was done the elephant would lift his head and march off to the place where the stone was to be used and gently lower it in position and then place his foot on it and press it down until it was properly imbedded in the mortar. They said it was formerly the cheapest and most satisfactory method for building foundations in Ceylon, but for some years past has not been followed.

The ties used in the railway are wood and the rails of the T pattern, and were formerly fastened to the ties by bolts through the flanges; but it was found that the bolt holes were frequently starting points for cracks which would result in broken rails, and therefore this method has been abandoned and spikes are now in general use. The ties are mostly of teak wood, which grows in abundance in Ceylon and makes a tie which, they claim in Ceylon and India, is much better than our oak. Some pressed-steel ties have been put

in, but as they cost about $2.50 apiece laid down in Ceylon, and the teak can be had for 40 and 50 cents, it is poor economy to use them. The standard depth of ballast is 15″ and three different types are used. One is broken stone, the second, gravel, and third, cabook, which is a laterite. Broken stone costs about 50 cents per cubic yard, and gravel and cabook 25 cents per cubic yard in the track. In some places ballast has been used to a depth of 3′ and over for leveling the track, because it was cheaper than to remove the ballast, fill in with earth and then replace the ballast. This sort of work is all done by native labor, and the track workman gets anywhere from 10 to 12½ cents a day, while 25 cents a day is very high pay for a foreman.

One of the most noticeable features in connection with the railways in both Ceylon and India is the fact that no crossing is left unprotected. At Kandy, which is one of the most important places on the road, the crossings are mostly elevated, and all other crossings throughout the country are protected by gates and watchmen. Trespassers are subject to fine and imprisonment, and if an animal, such as a cow or horse, is killed by a train, the owner is very careful not to let the railway officials discover the correct ownership of the beast, for if they do he is subject to a heavy fine for allowing it to be on the right of way. The railway stations are handsome buildings, all excepting three being built of brick or stone, and all of them are scrupulously clean. The grounds surrounding each station are decorated by beautiful flower gardens, and at a fixed date an inspection is made by the general manager and awards presented to the station master having the best kept grounds. The platforms are built of cement and of such a height that it is a comfortable step from the car to the platform, or from the platform to the car. The English type of carriages and goods wagons have been used almost exclusively until within the past three or four years, when the American type of coach and freight car have been coming in.

Each station is supplied with semaphore signal with a separate blade for trains running in each direction, and they are used only for giving stopping signals. The system of starting signals is somewhat complicated. When a train is ready to pull out, the station master rings a hand-bell and the guard of the train then looks around and sees that everything is all ready and blows a small shrill whistle, and if the engineer is ready he toots the whistle of his locomotive, which is answered by a second whistle from the guard, and after these operations the train moves off. The natives of Ceylon are quite intelligent in the handling of the railways and are employed as station masters and in all positions of like character. All the clerical work about the office is done by them and also all the firing of locomotives, and a few are employed as drivers.

The climate of Ceylon is hard on paint, and near the seashore the bridges are usually painted every four months and never allowed to go longer than six. Black paint, coal-tar and pitch are used for this class of work.

The railway system of India, which was the next country visited, is much more extensive than supposed by persons who have not looked into the subject. At the present time there are in operation in this country something over 18,000 miles of railway, of which about 12,000 is 5′ 6″ gauge, 4,600 metre gauge, and the remainder 2′ and 1′ 6″. The 5′ 6″ gauge was the first introduced, but it was soon found that many roads could not be made to pay operating expenses, and it was decided to use the meter gauge in building some new roads and also to change the gauge of some of that built 5′ 6″, in order to lessen the expense of operation. The South India Road is a notable example of the latter, as it was originally 40 to 50 miles long, and with a 5′ 6″ gauge, and did not pay expenses in the hands of a private company. The India government agreed to guarantee interest on the bonds of this road if the gauge was changed to one meter and the line extended. This was done, and at the present time the road is doing a large business, and it is found that the meter gauge is too narrow to carry it economically. This has occurred in one or two other places in India and in some places they have the meter gauge where they should have the 5′ 6″, and in other places they have the 5′ 6″ and should have the meter, and I think the general opinion is that it was a great mistake that the 4′ 8½″ gauge was not originally adopted.

In the Bombay Presidency, which is on the western coast, the Great Indian Peninsula Railway, with 1,498 miles of track, is the most extensive road. The great feature of the G. I. P. Railroad, as it is called, is its switchback or reversing station, a short distance out of Bombay, which is a very fine piece of engineering work. The Bombay station is said to be the finest in the world, and the ex-

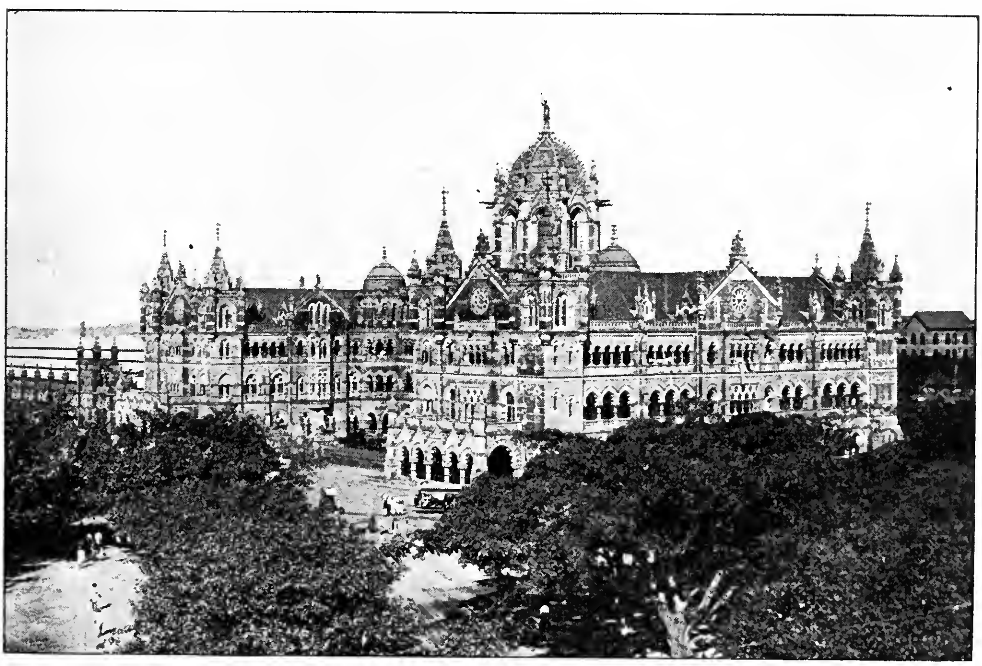


FIG. 12. BOMBAY STATION, G. I. P. RY.

terior probably is, but the interior is exceedingly disappointing. Almost any station in the city of Chicago would present a much finer interior appearance than this magnificent structure, as all the money has been spent on the exterior, which is quite characteristic of English railway stations. The illustration, Fig. 12, is a very good view of this station.

From Bombay we took a steamer to Kurrachee and there struck the Northwestern Railway, which is the largest single system in India and has 2,617 miles of line in operation. At Ruk Junction, about 250 miles north of Kurrachee, the Muskaf Boulan Railway branches off from the Northwestern and extends for a distance of about 300 miles through an exceedingly barren and desolate district across British Beloochistan to Chaman, just across the Afghanistan boundary, and forms the extreme western outpost of the British Indian government. This line was built and is maintained purely for military purposes and is probably one of the most interesting in the

Fig. 13.

Bridge at Entrance to Chuppa Rift, Muskaf Boulan Ry., Beloochistan.

world. It was built under the supervision of Sir James Brown, 213 miles being completed in thirty-three months, 42,000 men being at work under the protection of a body of 5,000 troops. The line passes through a desert 50 miles wide, and during the work all food and water were carried on camels for long distances. As the line was nearing completion cholera broke out among the men and 3,000 of them, mostly natives, died within one month. From Sibi north the line was originally built through the Boulan Pass and laid on the bed of the river. For several years it was kept open with only occasional breaks of small moment, caused by heavy rains. It was found, however, that what appeared to be a more feasible route for the line from Sibi to Bostan was through Chuppa Rift, and what has since been given the name of Mud Gorge. The line was accordingly laid on this route, the distance between the two points being 133 miles. Mud Gorge, however, developed unlooked-for difficulties, as it was found that the earth was of such an unstable character that the line was unsafe. On several occasions sections of it shifted 10 or 15 feet in one night and no amount of retaining wall or piling could be made to hold it in place. While attempts were being made to overcome this difficulty, in August, 1890, a cloudburst completely wrecked the line through Boulan Pass. At just about this time it was decided that the line could not be maintained through Mud Gorge and the only possible course was that of reconstructing the line through Boulan Pass.

Chuppa Rift, which must thus unfortunately be abandoned, is a remarkable freak of nature. The hill through which it passes is an enormous ridge of rock and the rift is a split or crack, varying in

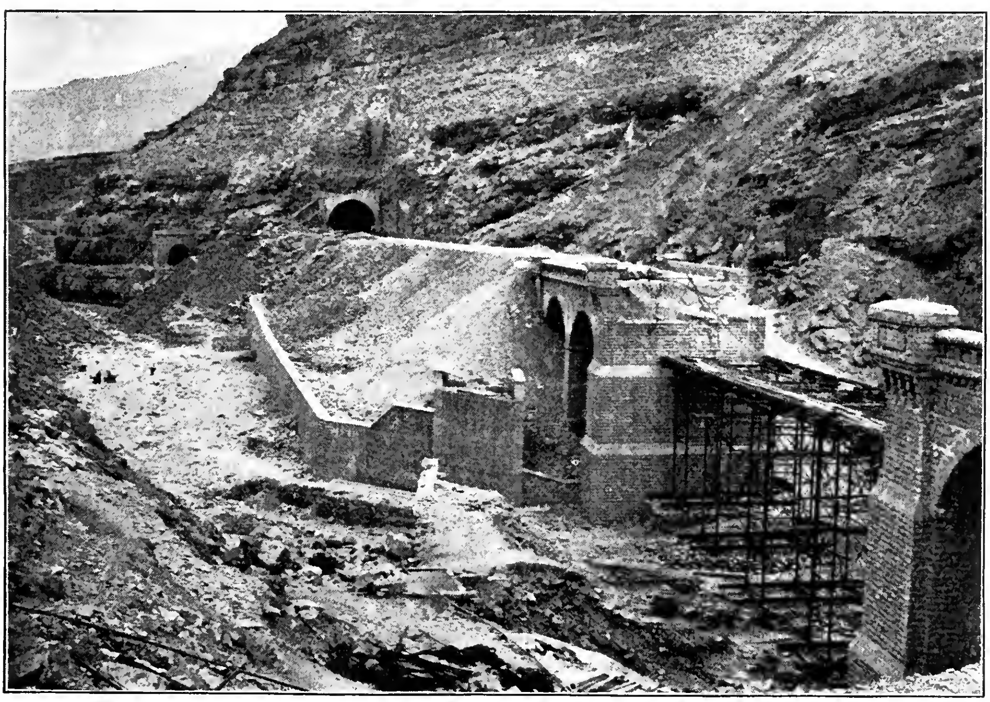


FIG. 14. BRIDGE IN BOULAN PASS., MUSKAF BOULAN RY., BELOOCHISTAN.

width from 10 feet up to 300 or 400, and looks as though it had been caused by the earth's surface being strained beyond its elastic limit. The railway approaches the rift through a long tunnel, crosses it over a bridge shown in illustration, Fig. 13, and immediately enters another tunnel. In its course through the rift, a distance of about 3 miles, there are several short tunnels and bridges.

The reconstruction of the line through Boulan Pass was begun in November, 1891, was well under way when we were there, and it was expected that it would be opened for traffic about the 1st of January next. This is probably the heaviest piece of railway construction in existence and the accompanying illustrations, Figs. 14 and 15, will give some idea of the bridges. It is a double track of

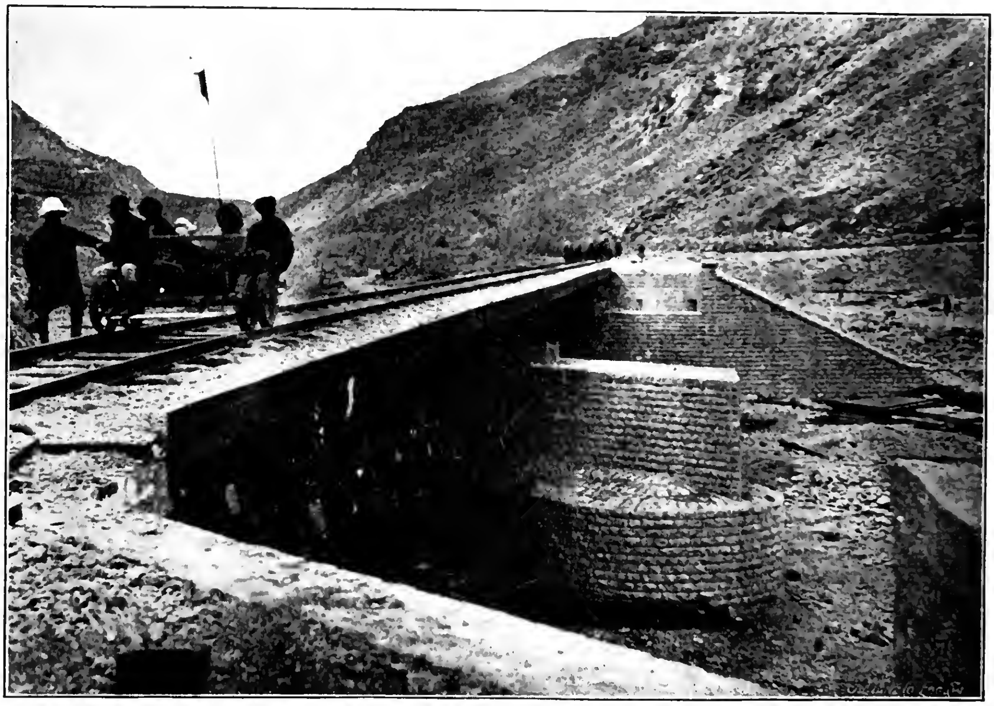


FIG. 15. BRIDGE IN BOULAN PASS, MUSKAF BOULAN RY., BELOOCHISTAN.

5′ 6″ gauge, the distance between centers being 14 feet, the weight of the rail 100 pounds per yard, the sleepers of pressed steel weighing 160 pounds each, and the prevailing grade 1 in 24. In one five miles there are fourteen bridges upwards of 60 feet in length, and the cost of that section was $58,000 per mile.

Beyond the pass the road crosses the summit of the range through the Kojak Tunnel, and while its dimensions may be familiar to some of you, I will give a few of the most important. The length of the tunnel is 12,800 feet and the radius of the arch is 14′ 6″ above the center and 29′ below. Half of it is level and the other is on grade of 1 in 40. It passes through shale rock and about three-fourths of it had to be timbered in building. It is lined throughout in brick, usually five rings thick, although in some places there are only four, and in others six and seven. There are two tracks, 5′ 6″ gauge, 12′

between centers, and the difference in the portal levels is 150 feet. The work was begun in April, 1888, and the tunnel opened for traffic January 1, 1892, 114 feet driven in one week being the best record. The work was carried on from both sides, a track of 5′ 6″ gauge being constructed over the top of the mountain for the purpose of carrying the material through to the further side. When the tunnel was built two shafts 14 feet square were put in for the purpose of ventilating, but the scheme was a failure, as the tunnel remained full of smoke. Finally the shafts were closed as an experiment and the smoke immediately cleared out, and since that time there has been no difficulty with ventilation.

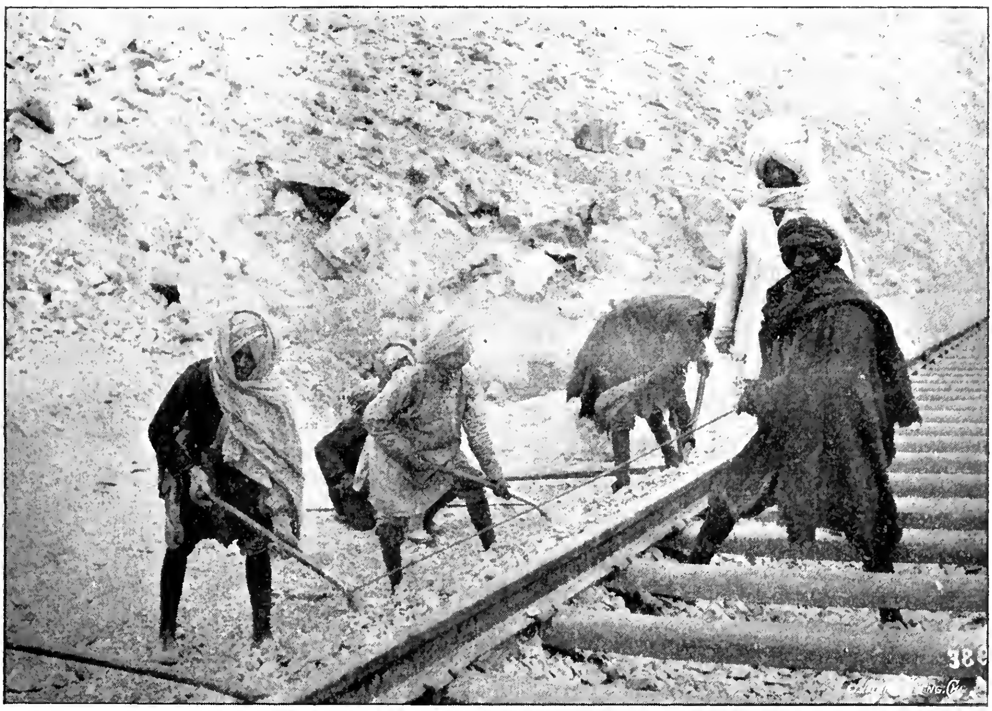


FIG. 16. TRACK LABORERS ON THE MUSKAF BOULAN RY., BELOOCHISTAN.

The illustration, Fig. 16, gives a good idea of the appearance of the laborers on the railways of Beloochistan and northern India, and also shows the manner in which they operate a shovel. They have very little strength in their arms, their muscles all being in their legs. A shovel filled with ballast is more than one man cares to manipulate and consequently one man pushes the shovel under the ballast and another, by means of a rope attached near the lower end of the handle, drags the load along. This division of labor seems to do very well and the men will manage to handle a reasonable amount of ballast if given sufficient time.

One of the great features of the railways of India and Ceylon is what they call the trolley car. The natives, having no strength in their arms, are not able to pump our hand-cars, but they can get on the rails behind a car and push it at a speed of ten miles an hour on the level, one man running on each rail, as shown in the illustration

Fig. 17. A good brake is put on each car, and when a grade is reached it is let loose. We went down through the Kojak Tunnel and into Chaman on one of these cars at a speed of between 35 and 40 miles an hour, and a more exciting ride I never had.

All the bridges on the Muskaf Boulan Railway and also the Kojak Tunnel have a fort at each end where guns can be mounted, and as we were winding along through the mountains it was a common thing to see sentinel towers on top of the high points commanding the railway.

The best road in India is beyond doubt the East Indian Railway. This line operates the fastest train in the country and has the finest motive power, while its roadbed is fully equal to that of any of the other lines. There are 1,843 miles in the system, of which 474 miles is double track. The main shops of the locomotive department are

Fig. 17. Push Car and Coolies, Indian Ry.

located at Jamalpore and employ about 5,000 men. The only rolling mill in the country is a part of these shops and in it a large amount of scrap iron is worked into merchant bar, some of which is used by the road and the remainder sold. A complete system of semaphore signals is being put in at all small stations, which consists of a home, distant and starting signal for trains going in both directions. At the large and important stations interlocking plants are being installed.

We went into Calcutta over the East Indian Railway and there

found in the great docks, which have been recently completed, the greatest engineering contract we saw during our trip. It will be impossible for me in this talk to give you a description of this work, and as full accounts of it have been published many of you are doubtless familiar with it. From an engineering standpoint they are a wonderful success, but just at present the great and all-important question of their financial success or failure is hanging in the balance.

From Calcutta we went up to Darjeeling, the great summer resort in the Himalayan Mountains, and the nearest point to Calcutta where cool weather is to be found. We took the Bengal State Railway from Calcutta to the foot of the mountain range, and there we took the Darjeeling Himalayan Railway, which is one of the most interesting we visited. The gauge is 20 inches, the road is 50 miles in length, and in that 50 miles the rise is over 8,000 feet. We left the foot of the mountain in summer clothing and sweltering with heat at 8

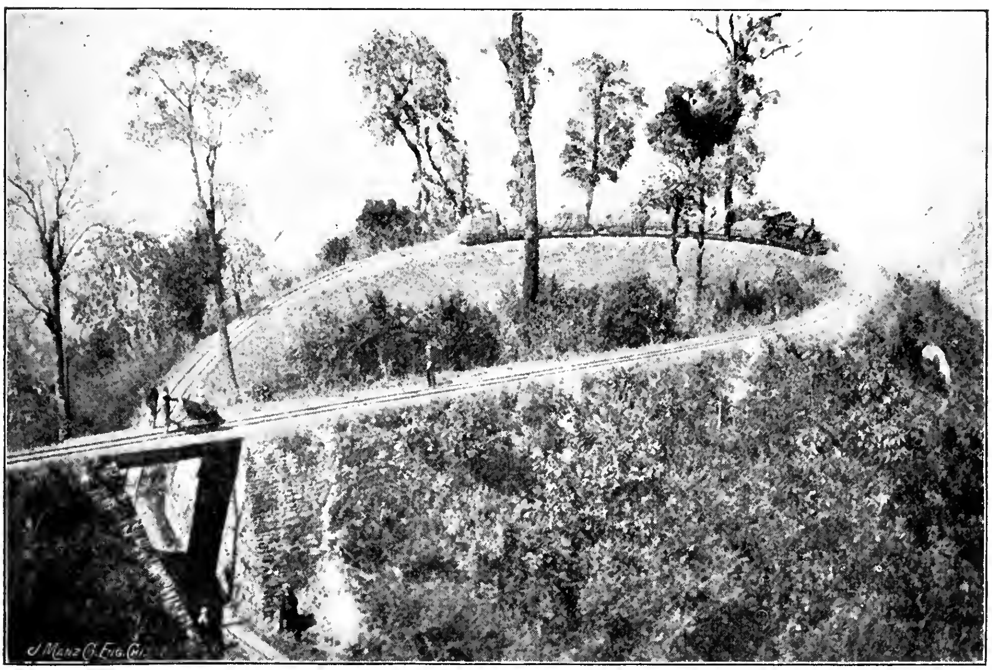


FIG. 18. SPIRAL CURVE 60′ RADIUS ON THE DARJEELING HIMALAYAN RY., INDIA.

o'clock in the morning, and at 3 o'clock in the afternoon we had to wrap our steamer rugs around us and nearly perished then with the cold. There are four spiral curves on the line similar to the one shown in Fig. 18, the radius of which is 60 feet, and also six or seven switchbacks. The rainfall in this section is heavy and some extensive retaining walls are necessary for preventing washouts.

The all-important railway engineering feature of India is the question of the sleeper, or railway tie. I do not know what the Indian engineers would do to pass away the time if it was not for this tie, for I never knew of two of them getting together without having a discussion on the subject. One man will declare to you that the only proper tie to use is the peapod sleeper (what we call the pressed

steel tie) and another will declare the cast iron pot sleeper to be the best, and still another will say neither of them is good, and that wood is the only proper material to use. As far as I was able to gather, however, the concensus of opinion is that if a good wooden sleeper can be obtained at a cost not greater than 75 cents apiece, it is foolish to use metal of any kind. The government engineer recently wrote a paper, which was copied in this country, in which he condemned the peapod or pressed steel sleeper, but at the time the paper came out the government was building the Muskaf-Boulan railway and using this same steel sleeper. It seems rather strange that the engineer should take the stand he does and at the same time the sleeper he condemns should go into railways of the government. At the present time the cast iron pot sleeper is used more than the pressed steel, but advocates of the latter are making a very hard fight to have it more widely introduced. I hope in the near future to be able to present to the society a paper on the subject of metal ties in which I shall be able to treat this subject more fully.

Returning to Calcutta we took a steamer for Rangoon, Burmah, and there took the Burmese State Railway and went north as far as Mandalay. The line passes through a succession of paddy fields and swamps, and while there are no engineering features of note on the line, the engineers surely performed a remarkable feat by remaining in the country long enough to build the line—that is, if the sample of heat given us was representative. At Amarapura the railway operates a very efficient ferry, for transferring goods cars across the Irrawaddy. The banks of the river are 40 or 50 feet high, and down these the tracks are laid on a gradual slope. The lower end of the tracks is connected by means of a girder to a barge which is firmly anchored out in the stream a short distance. At the upper end of the slope a winding engine is placed and the cars are attached, one at a time, to a wire rope and lowered down the track across the girder and barge to the transfer barge which is moored alongside. The transfer barge when loaded is towed across the river by a steamer which also does duty as a passenger transfer, as the passenger cars are not taken across the river.

One of the great sights of Rangoon is the elephants working in the saw-mills and lumber yards. They were formerly employed in all the large mills but at present only one continues to use them, and in this yard we saw fourteen at work at every kind of work, from sweeping the floor to piling up timbers which were said to weigh one ton. You can, by looking at Harper's Weekly of December, see some photographs I took of these elephants, which will give you a much better idea of the manner in which large timbers are handled than I can give by a description. The photographs are said to be taken by Mr. W. H. Jackson, but that is an error—typographical, I suppose.

We saw an elephant walk up to a stick of timber about 14 inches square, 25 to 30 feet long, which they said weighed one ton, get down on his knees, run his tusks under it, throw his trunk over it, get up and carry it to a pile of similar sticks and put it down with

one end resting on the pile and the other end on the ground. He then walked around to the end on the ground, curled up the end of his trunk and with it pushed the timber up on top of the pile and then went to the other end and pushed it up so it lay even with the other timbers.

From Rangoon we went to Singapore, and then up to Bangkok, Siam, where the king is building a railway about 160 miles in length. We were there during March, 1895, and at that time work on the line was progressing rapidly at a number of points, in both the difficult hill section and on the plain. About thirty miles of the main line was completed and we were taken over it by Herr Bethge, director general of railways. Numbers of stations were either complete or nearly so, and in view of the great activity shown on all sides I was somewhat surprised in reading Henry Norman's recent book, "The Peoples and Politics of the Far East," bearing the date of 1895, to find the statement that, "Up to the present only a few kilometers of the line have been laid and of these a great part is merely for the purpose of transporting material and will not form part of the permanent way, while the heavy portion of the work in the hill sections is practically untouched"; and, also, "There does not appear to be the slightest probability of this line ever being completed under the present regime except, perhaps, as far as the king's palace at Bang-pa-in."

These statements are untrue and do a great injustice to men who are laboring hard and under particularly difficult conditions.

From Bangkok we went back to Singapore and took a steamer from there for Java, and the little island of Java, which looks like a mere speck on most of our maps, is about 800 miles long, 200 miles wide, and has over 23,000,000 inhabitants.

There is in operation about 1,500 miles of railway, most of which is owned and operated by the government, and is 3′ 6″ gauge. There is a continuous line from end to end of the island, with a break of gauge near the center, where there is a section of 4′ 8 1-2″ gauge about 20 or 30 miles in length. The track is kept in excellent condition and would be a credit to any country. The ballast is gravel and broken stone. About 12 inches outside of each end of the ties a nice little rip-rap wall is built up to a height of 8 or 10 inches, which holds the ballast in place and presents a very neat appearance. The ties are completely covered with ballast, excepting one at the center of each rail, which is left open for drainage. Outside of the track on each side the sod is kept in perfect condition over the entire right of way of the railway. This sod is mown by the natives in a peculiar fashion. The implement used is a sickle about the shape, but smaller than commonly used in this country for clipping grass, but is fastened on the end of a broomstick, and the operator stands perfectly straight, and as he moves slowly along swings this implement around his head, and every time it strikes the grass it clears off a space about 6 or 8 inches in diameter. The result is a lawn mown as perfectly as though done with a modern lawn mower. The bridges are all very good, and come out from Europe, together

with the capstones for the foundations, there being very little stone in the country that is of sufficiently good quality for that purpose. The piers are built of concrete, mixed with Portland cement, and whitewashed so that they make a very handsome appearance. The Dutchmen rule Java with an iron hand. While I was in the office of one of the station masters of the railway messengers would come in to deliver notes. When a messenger reached the officer's desk he would fall on his knees, place his hands before him in a very abject attitude, slip the message into the hands of the station master or on top of the desk, and then back off and go out of the room as quickly as possible.

From Java we took a steamer to West Australia and there found the railway mostly belongs to the goverment, is 3′ 6″ gauge, and about 300 miles in length; but as there are only about 40,000 people in the colony, you can imagine it is not a very important affair. At Freemantle a very interesting piece of engineering work is under way in the construction of a harbor and the cutting through of a ledge of rock which prevents vessels of deep draft from entering the Swan river. The river is deep and after the ledge is removed ocean steamers will be able to go all the way up to Perth, a distance of some 14 miles. The work is all done under water, the drilling being done entirely by hand from staging. The blasting is done with dynamite, and the spoil removed by English endless chain dredges. The engineers in charge state that the entire cost of drilling, blasting, dredging and dumping the spoil into the sea is less than 75 cents per cubic yard.

The new railway station at Perth is a very nice looking and well arranged building, just completed.

From West Australia we took a steamer to Adelaide and visited the colonies of South Australia, Victoria, New South Wales, Queensland, New Zealand and Tasmania. It is out of the question for me in this talk to give a complete description of the railways in all these colonies and I will give you some of the most important characteristics. The most important and perplexing question from every standpoint is that of the gauge of track. In South Australia they have two gauges—5′ 3″ and 3′ 6″. In Victoria they have a 5′ 3″ gauge and in New South Wales 4′ 8 1-2″. A through service is maintained between Melbourne and Sydney, a part of the distance being over a 5′ 3″ gauge and the remainder over a 4′ 8 1-2″, all business being transferred. This gauge question furnishes material for the fertile brain of the inventive crank, and inventions on this line are as numerous in Australia as they are on couplers in this country. The best railway we saw in all our travels was the New South Wales government railway. The main line has a complete interlocking plant at every station and the system of signaling is so complete that it would seem impossible to have accidents. The cars are, most of them, of the American type, and Pullman sleepers are run on the main lines. The engines are mostly of the English type, although some have been sent from this country.

Another very serious question in all of Australasia is that of the

labor organizations. The labor party is of sufficient power to control legislation and as a result of this and political management none of the roads are paying operating expenses. Advocates of government ownership of railways have in this country an example of the disastrous results which must follow any such control, and no more clinching argument could be advanced against it than a complete showing up of the condition of affairs as they actually exist.

In Japan there is about 2,500 miles of railway in operation, of which some 500 miles belong to the government and the remainder to 13 or 14 private companies, having systems ranging from 5 miles to 600 miles in extent. The largest single system is that of the Nippon railway, which comprises about 600 miles in operation and 200 under construction. The aggregate capital invested constructing 1,879 miles of railway, which was the total miles in operation in December, 1892, is given as 94,163,836 yen, which would be equivalent to a little over $25,000 per mile. During the year 1892 the number of passengers carried per mile of track was 14,300 and the tons of goods per mile of track was 1,500. The gauge of track is universally 3′ 6″.

Many of the lines were constructed and operated under the supervision of European engineers, but the Nippon Railway is a notable exception to this, as it was built entirely under the supervision of Japanese engineers, by Japanese capital and none but Japanese have ever been connected with its operation and management. The average cost of the railway per mile is only about $16,750, which speaks wonderfully well of its engineers. From an engineering standpoint the rack railway on the Yokogawa-Karuisawa section of the government railway is the most interesting in Japan, and is described by Mr. Francis H. Trevithick in a paper read before the Asiatic Society of Japan, as follows:

"The question of making the connection between Yokogawa, 1,263 feet, and Karuisawa, 3,080 feet above sea level, has been the cause of much thought and consideration to the railway engineers. Minute surveys over the Usuitoge (pass), an extremely rough portion of the Nakesendo highway, had been made in past years. They resulted in proving that to lay an ordinary railway over the pass would, in the first place, require a large expenditure, and when completed on gradients of one in forty, with sharp curves, it would be about 17 miles long. At about this time two young engineers returned after 1 1-2 year's trip to America and Europe, sent to study railway construction, and they were greatly taken with the Abt track railway system for passing over rough country. And from this and other circumstances the adoption of the Abt system for this district was decided upon, and fresh surveys of three different routes under this system were begun in April, 1890; they are:

First—The Wami Route—This, the most southern of the three routes, leaves the Karuisawa plain by the Wami pass, and proceeds on its downward course by the hamlets of Onga, Akahama and Arai, and enters Yokogawa Station. The distance is 7 miles 50 chains, of which 2 miles 64 chains are on a gradient of 1 in 40, and

4 miles 67 chains incline of 1 in 15. Tunnels are 17 in number, with an aggregate length of 183 1-2 chains; or 2 miles 23 1-2 chains.

Second—the Iri-Yama Route.—This is the central route. It emerges from the Karuisawa plain by Mount Manatcho, and skirting around Mount Inamuro proceeds on to Akahama, and thence to Yokogawa with 1 in 40 gradient. Its length would be 7 miles 36 chains, of which 2 miles 64 1-2 chains are on a gradient of 1 in 40 and 4 miles 51 1-2 chains on 1 in 15. The tunnels would be 21 in number, with an aggregate length of 154 chains or 1 mile 74 chains.

Third—The Nakao Route.—This is the most northerly route. It begins at the Karuisawa Station and follows the new road (Nakasendo) in the Nakao Valley and joins via Sakamoto the existing railway at Yokogawa. Its length is 6 miles 77 1-2 chains, of which 2 miles 28 chains are on an incline of 1 in 40, and 4 miles 49 1-2 chains on 1 in 15. Tunnels 26 in number, with an aggregate length of 221 chains 88 links, or 2 miles 61 3-4 chains.

"When the results of the preliminary surveys of these alternative lines were compared it was seen that the Wami line, though encumbered by one long tunnel of over 60 chains, had the smallest number of them; that the Iriyama line was hampered by numerous curves; and that the Nakao line, by following the main road in close proximity, had an ample means of supplying material. A second survey of the Wami, and the Nakao line, the results of which proving satisfactory to the Nakao line, it was finally adopted in February, 1891.

"The line was commenced in March, 1891. It being laid out over a wild district, has necessitated engineering works of no ordinary nature, rocky hills having to be cut away and ravines filled up, extremely steep gradients introduced, as many as twenty-six different places within this short distance having had to be pierced by tunnels. Thanks to the fact of the line being located along the public roadway, and the latter having thereby afforded ample means of transportation and distribution by means of the horse tramway, no dearth in the supply of material has been experienced at the places where the works were being carried on.

"The experience gained from the practical illustrations of the effects of earthquake phenomena on bridgework during the great earthquake of the Owari and Mino provinces being availed of, some alteration of the designs for the brick arches and piers of the bridges on this railway was necessitated. The principal bridge is over the Usui river; it has four spans of 60 feet, built on brick arches, and it is 110 feet above the ground. There are 2,200,000 bricks in this structure.

"The construction of this line was begun in March, 1891, and opened for traffic on the 1st of April, 1893. It was therefore completed in 25 months. The principal works connected with this line were: Earthworks, cuttings, embankments, deviation of roads, etc., etc., 89,404 tsubo;* tunnels, 26 in number, with an aggregate length

*Note.—A tsubo equals 8 cubic yards.

of 14,644 feet; bridges, 18, with an aggregate length of 1,471 feet; culverts, 20; rails laid for the main line and the sidings, 8 miles 44 chains; a passing station at Kuma-no-taira, which is half way up the gradient; and other buildings, 651 tsubo.

"Without going into the advisability of an alteration in the general construction of the railway, and whether it is wise, or otherwise, to adopt a new system from the financial and military point of view, the engineer in charge and his assistants are to be congratulated on the way the works are constructed, of which any country might be proud."

In this account the fact is omitted that the cost of the line as constructed by the Japanese was within the appropriation made for its construction, and was about one-half the amount estimated by English engineers for the line advocated by them. Practically all the railways in Japan are now being operated exclusively by Japanese, and when it is remembered that the first line in the country was opened in 1872, and that only a few years before that date the country was closed to foreigners, it will be seen that the progress of the country is almost magical.

I have endeavored in the foregoing remarks to give you some idea of the railways in the countries visited by the commission up to July 25, when I left it; and in closing I wish to say that each one of these countries has conditions peculiar to itself, which those building and operating the railway lines seem to have in every instance comprehended and met in a greater or less degree; but I am indeed thankful that it is my lot to live in a country where the conditions require a railway service which gives the traveler the most comfortable cars, the fastest and smoothest running trains, the best meals, and, in fact, luxuries which are not dreamed of in any of the many places in which it has been my pleasure to travel.

III.

NEW EXPERIMENTAL DATA FOR FLOW OVER A BROAD CREST DAM.

By Thos. T. Johnston and Ernest L. Cooley, Mems. W. S. E.

Field Observations and Data.

The apparatus used is shown in Figs. 19-22, and consisted essentially of a level straightedge fixed on a frame, and a vertical rod sliding in a tee-head fixed on a horizontal rod, the horizontal rod sliding in turn on top of the horizontal straightedge. These vertical and horizontal movements were graduated to read to feet and hundredths. The bottom of vertical rod was shod with an iron plate with tip squared and $\frac{1}{8}''$ by $\frac{1}{4}''$ in plan. The vertical rod side of frame was covered with planed matched stuff extending like a cutwater 3 feet beyond the front corner of the dam, both up stream and down the face of dam. This cutwater was chamfered to a thin edge on the back side and was designed to reach up stream beyond any disturbance due to obstruction of current by frame. The working side of cutwater was a planed wood surface from end to end, with no projections in water. The tip of the vertical rod moved parallel and 2 inches from this vertical plane surface.

This apparatus was placed on top of dam parallel to and 10 feet from north abutment and was adjusted normal to axis of dam, as shown in Fig. 22. It was securely anchored in place by rock ballast placed on a shelf in frame. The straightedge was fixed in place on frame by two bolts, the down stream bolt being adjustable in slotted hole, and was leveled with an ordinary carpenter's spirit level. The cope of this dam was Joliet limestone cut smooth and true in a planer on all sides, and was 5 feet wide on top and 1 foot thick.

For convenience of manipulation in the field the graduations were made with zeros arbitrarily located outside the range of work. The vertical rod moved normal to the horizontal rod between the fixed tee-head and a movable follower, which was held in place by a recessed cylindrical button and a pair of stout rubber bands, being a kind of friction clamp, which worked very well. A plate on back of tee-head kept the vertical rod from rocking. For convenience of observation the horizontal rod was graduated with two zeros, one opposite vertical rod and the other 3 feet back.

The operation of locating a point on the water surface was as follows: First, set the vertical rod in the horizontal rod to an even hundredth of a foot; second, slide the horizontal rod along the horizontal straightedge until the tip of the vertical rod just touches the water and read graduation to the nearest hundredth of a foot; third, record the first reading as ordinate, y, and the second reading as abscissa, x. With two men, one observing and one recording, it is easy to locate one point every 30 seconds.

Johnston and Cooley—Flow Over Broad Crest Dam.

FIGURE 19.

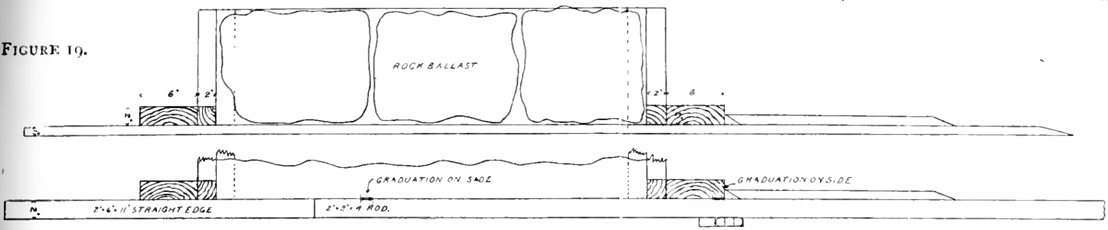
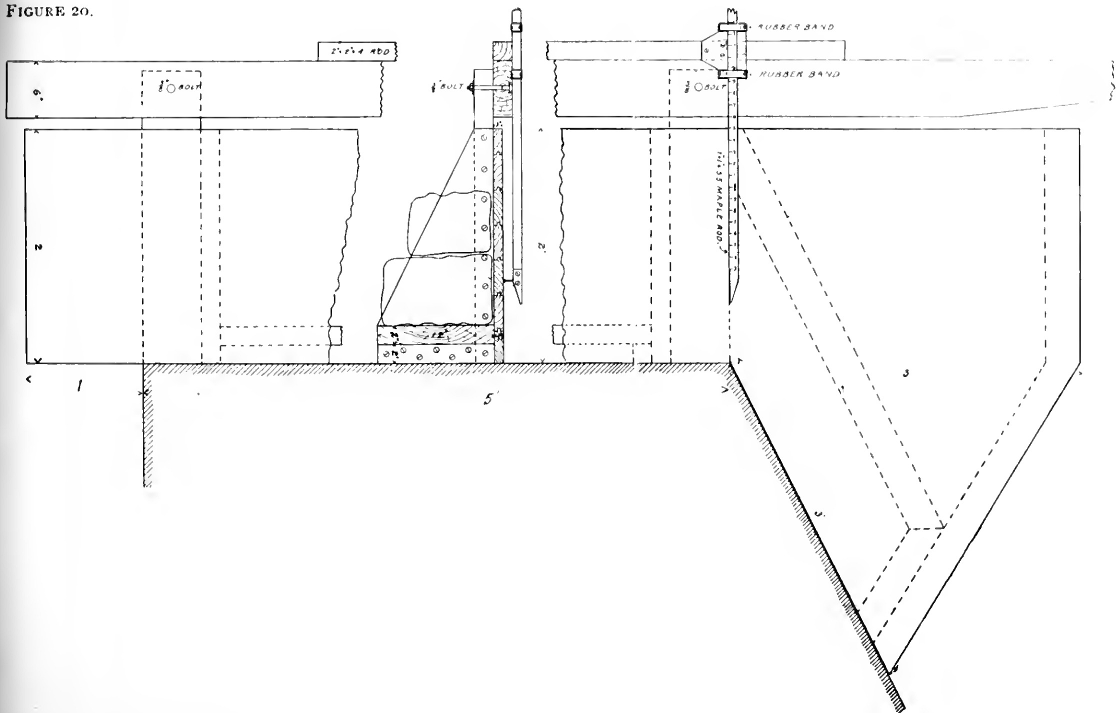


FIGURE 20.



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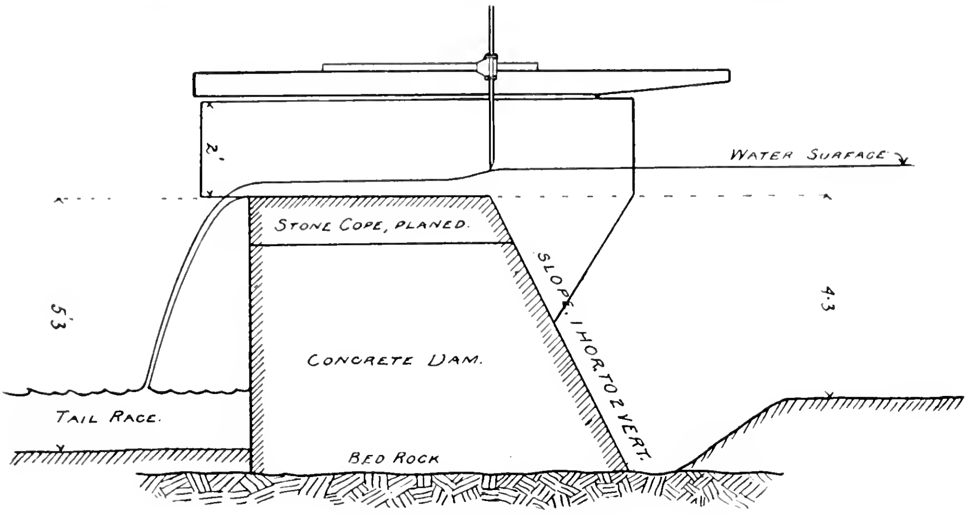

FIG. 21. ELEVATION.

The crest of dam was located by a similar operation on the same scale by the same rods at both front and back corners of cope. For ordinates the tip of the vertical rod was slid along top of cope 3 or 4 inches to insure against measuring in bottom of any accidental pit in surface of stone. For abscissae the vertical rod was slid 0.01 foot further down and tip moved against side of stone, the reading at front corner of crest was corrected 0.02 feet for thickness of tip and slope in face of dam. The location of crest of dam was checked before and after locating water surface and no change found.

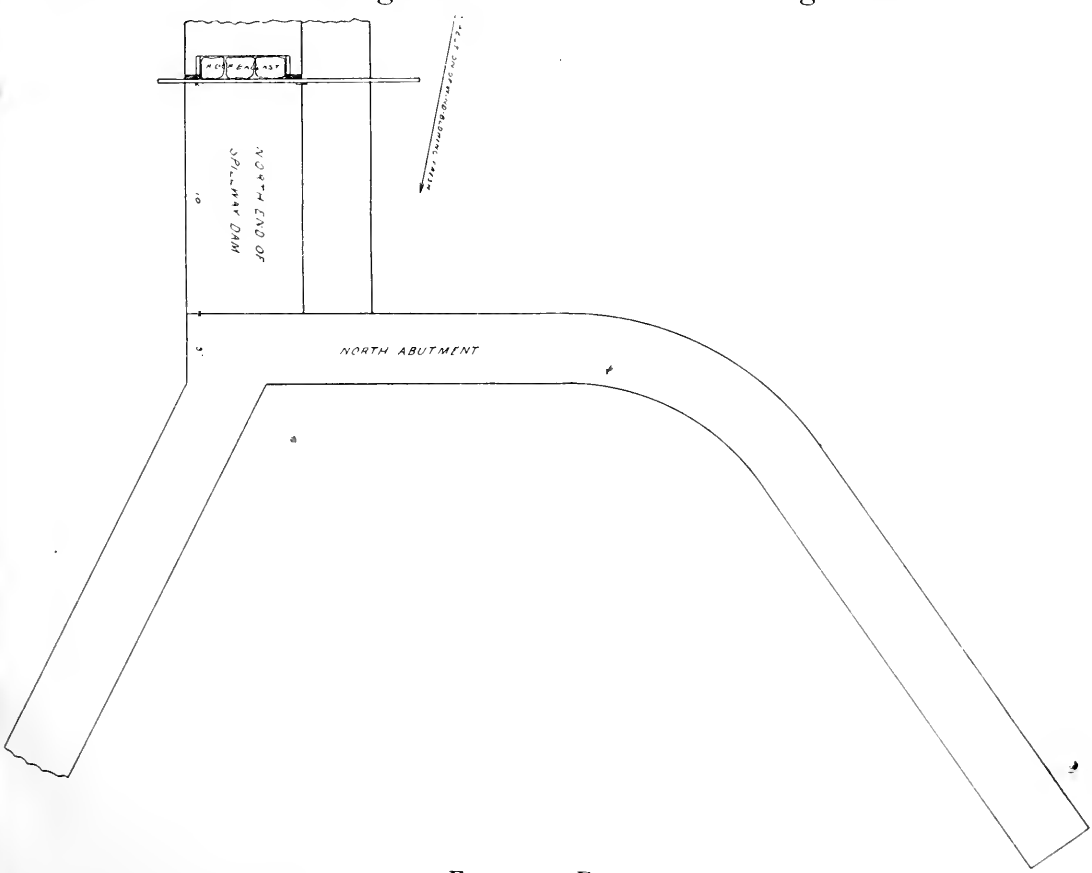

FIG 22. PLAN.

Three sets of observations were made, one in the morning and two consecutive sets in the afternoon. Each set was measured from down stream to up stream and back to check errors and cover change in stage of water. The design was to locate all points within 0.005 feet, and with that purpose in view abscissae were read to the nearest 0.01 feet and ordinates to 0.001 feet. Certain sources of error may be briefly mentioned. The wood work was a good class of carpenter work. The straightedge was made from a piece of selected clear white pine which had been in the shop more than a year; it was finished with a carpenter's plane and tested by drawing a line, turning over and reversing; after graduating it was painted with shellac and was probably not as much as 1-16 inches out of line vertically when used.

This straightedge was set level with an ordinary carpenter's spirit level with bubble radius of about 3.5 feet and was checked, without discovering any change, twice the next day before observing, reversing the level each time. The straightedge was probably out of level less than 1-16 inches in the 7 feet used in measuring curve. The graduations were projected off a N. Y. leveling rod laid parallel and clamped to the piece to be graduated, using a carpenter's try-square and scribing with the point of a knife; assuming the leveling rod to be correct some of these graduations may have been 0.001 feet in error. After graduating the surfaces were painted with shellac. The vertical rod was made of maple and the horizontal rod of white pine. The tip of the vertical rod would easily define within 0.001 foot.

By observing in sets of two, measuring points on the water surface forward and back in a consecutive manner, and using the mean of these two curves the error due to falling stage of water was eliminated, assuming the time intervals and fall in stage to be uniform. The error due to falling stage was probably quite small under the conditions which prevailed at the time.

The wind blew a moderate breeze in a direction indicated in Fig. 22, and made ripples on the surface of the water an inch or two high at times. Fortunately the cutwater board shielded the water surface under observation. In the morning, oscillation of water surface under observation was noticed, the breeze being somewhat unsteady. This oscillation was most noticed near the bow of the cutwater. The average slope curve began about 1.5 feet back of cutwater bow. The errors due to oscillations in any one curve may not exceed 0.01 foot, and would of course be much less in the average of three sets of two curves each.

I will not attempt to estimate the distortion of water surface due to skin friction and internal work caused by cutwater board, but will note in passing that the water being somewhat roily a slight boiling motion was noticed near bow of cutwater; however, the distortion shown by reflected light did not appear of much magnitude. The apparatus, being placed 10 feet from abutment, was fairly free from distortion from that source; the rock-faced masonry of abutment distorting water surface less than 2 feet out at back side of dam.

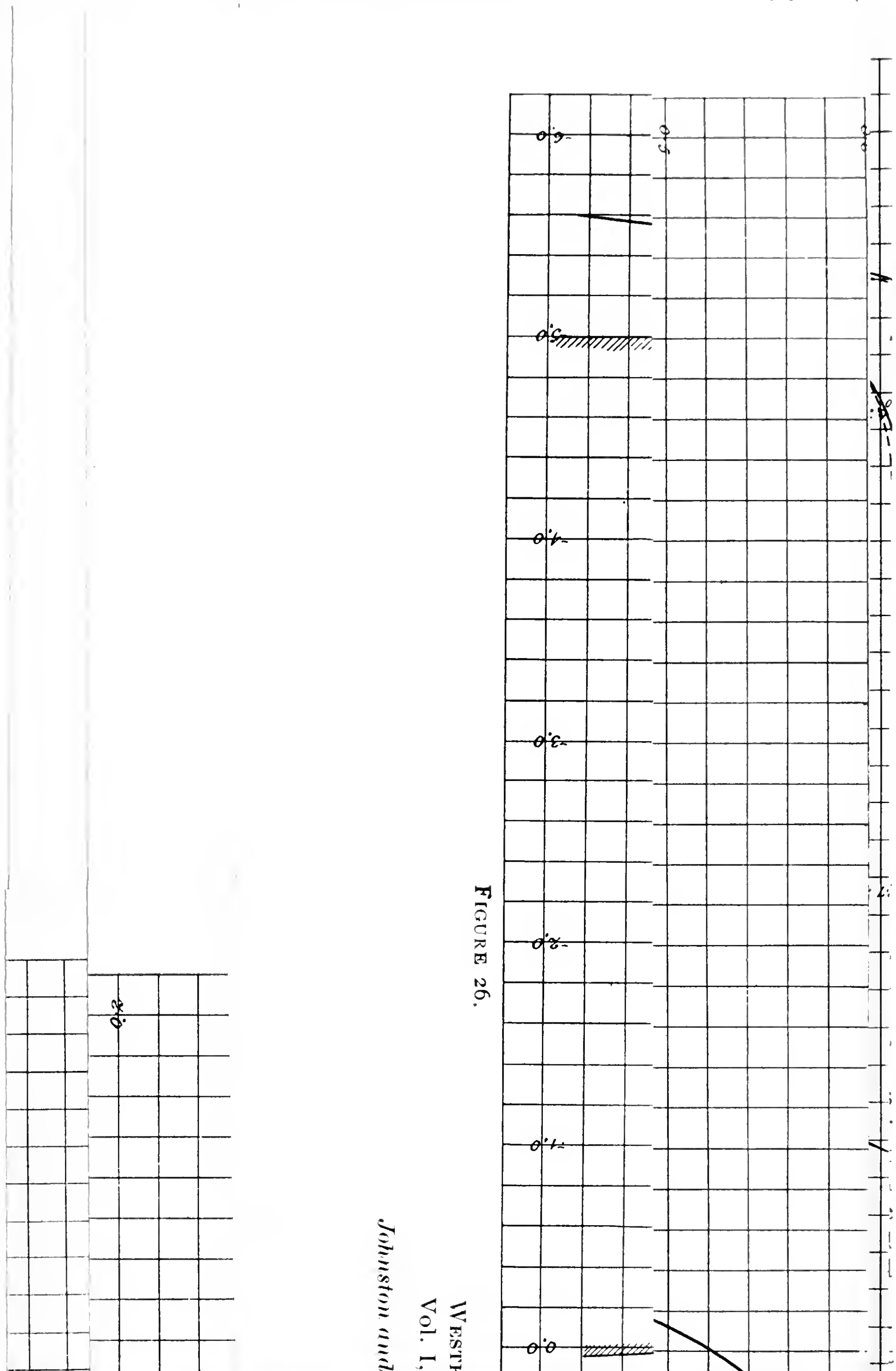

FIGURE 26.

would have required ordinates at less intervals than 0.01 feet to determine this. If it should ever be my good fortune to make similar observations I would try for shorter intervals, both here and above in pool. My impression at the time in the field was that intervals of 0.01 feet were close enough.

ERNEST L. COOLEY.

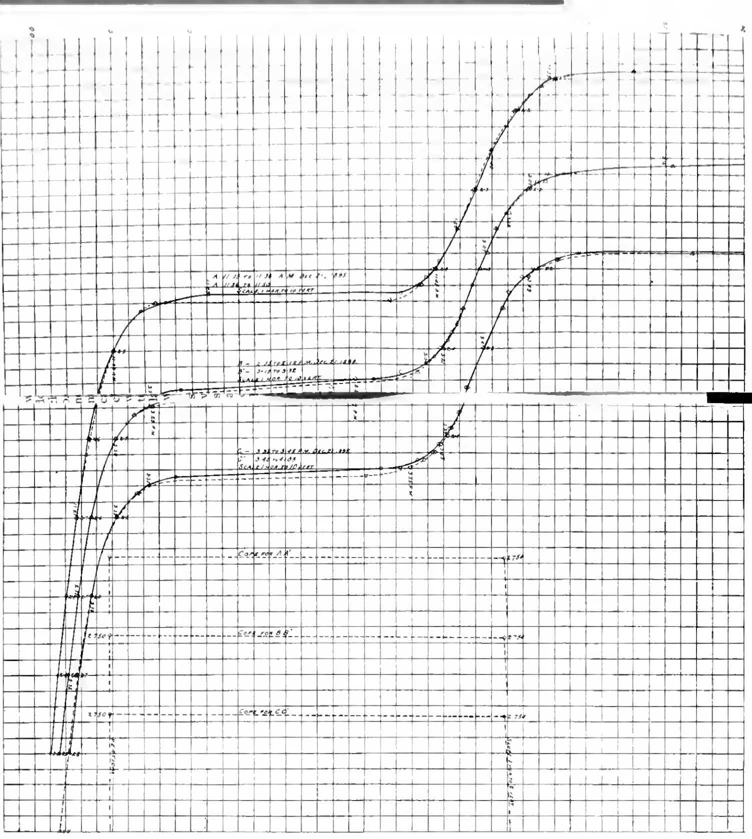

FIGURE 24.

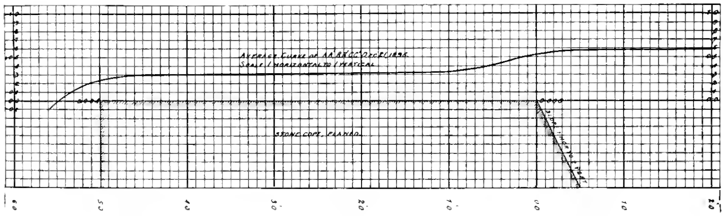

FIGURE 25.

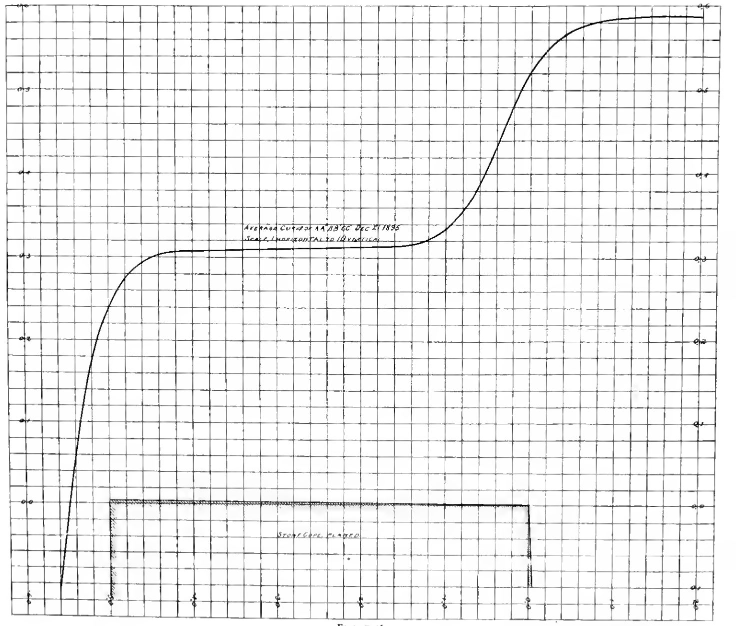

FIGURE 26

The pool in front of dam being about 5 feet deep with only about 0.6 feet going over dam, there was practically no velocity of approach. The front slope of dam was 1 hor. to 2 vert. It is an observed fact that the steeper the front slope of a flat-topped dam the more pronounced is the surface curve. Water in the pool above a weir at considerable depths appears to approach at a velocity similar to the surface velocity at an equal distance from the crest of the weir.

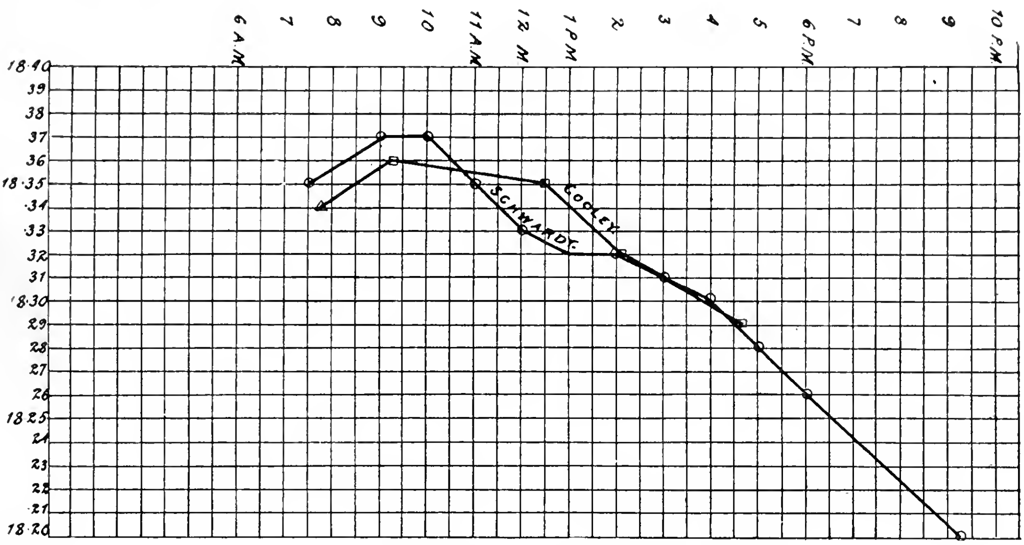

FIG. 23. RIVERSIDE GAUGE, DEC. 21, 1895.

The Riverside Gauge readings, shown in Fig. 23, were read on a gauge graduated to 0.1 feet and were estimated to 0.01 feet. The surface of the water at gauge was not still, and some of the readings may be in error ± 0.02 feet. This gauge is about 7,000 feet up stream from the dam.

Table No. I is a record of the co-ordinates of the three sets of curves marked AA′, BB′ and CC′. The curves measured from down stream to up stream are marked A, B and C, and the curves measured in the opposite direction, A′, B′ and C′, shown as dotted lines in Fig. 24. Columns y and x give the co-ordinates as recorded in the field, and columns Y and X give co-ordinates of same points referred to zero = up stream corner of dam.

The three sets of curves were first platted from the field-notes to a large scale shown reduced in Fig. 24. The co-ordinates for three sets of average curves were scaled to the nearest 0.001 feet from these plats and this data reduced to one average curve, shown in Figs. 25 and 26. The co-ordinates of this average curve are given in table No. II, column x, being abscissae referred to field zero, and columns Y and X being ordinates and abscissae referred to zero = up stream corner of dam.

In conclusion, I will say it is not certain that the tangent joining the two parts of curve is really a straight line as shown. It would have required ordinates at less intervals than 0.01 feet to determine this. If it should ever be my good fortune to make similar observations I would try for shorter intervals, both here and above in pool. My impression at the time in the field was that intervals of 0.01 feet were close enough.

ERNEST L. COOLEY.

TABLE I—DATA FOR FLOW OVER SPILLWAY DAM BELOW RIVERSIDE, ILL., DEC. 21, 1895.

A	Field Co-ordinates of Curve A.		Co-ordinates referred to zero = front corner of dam.		A′	Field Co-ordinates of Curve A′.		Co-ordinates referred to zero = front corner of dam.	
	Vertical.	Horizontal.				Vertical.	Horizontal.		
Remarks.	y	x	Y	X	Remarks.	y	x	Y	X
Front cor. of dam	2′.754	2′.98+3.′—0.′02	0′.000	0′.00		2′.15	4′.59+3′	+0 .604	+1′.63
	3 .00	0 .20+0	— .246	—5 .76		2 .16	3 .60+3	+ .594	+0 .64
	2 .90	0 .30	— .146	—5 .66		2 .17	3 .43+3	+ .584	+0 .47
	2 .80	0 .41	— .046	—5 .55		2 .20	3 .09+3	+ .554	+0 .13
11–21 A. M.	2 .70	0 .54	+ .054	—5 .42	11–40 A. M.	2 .25	2 .79+3	+ .504	—0 .17
	2 .60	0 .69	+ .154	—5 .27		2 .30	2 .57+3	+ .454	—0 .39
	2 .50	0 .99	+ .254	—4 .97		2 .35	2 .36+3	+ .404	—0 .60
	2 .45	1 .35	+ .304	—4 .61		2 .40	2 .05+3	+ .354	—0 .91
	2 .44	1 .67	+ .314	—4 .29		2 .42	1 .91+3	+ .334	—1 .05
11–27.	2 .43	2 .21	+ .324	—3 .75		2 .41	1 .97+3	+ .344	—0 .99
	2 .43	4 .65	+ .324	—1 .31	11–45.	2 .40	2 .09+3	+ .354	—0 .87
	2 .42	4 .85+0	+ .334	—1 .11		2 .39	2 .13+3	+ .364	—0 .83
	2 .40	2 .08+3	+ .354	—0 .88		2 .40	2 .06+3	+ .354	—0 .90
11–32.	2 .35	2 .36+3	+ .404	—0 .60		2 .42	1 .88+3	+ .334	—1 .08
	2 .30	2 .60+3	+ .454	—0 .36		2 .44	1 .51+3	+ .314	—1 .45
	2 .25	2 .80+3	+ .504	—0 .16		2 .44	1 .54+0	+ .314	—4 .42
	2 .20	3 .13+3	+ .554	+0 .17	11–49.	2 .50	1 .00	+ .254	—4 .96
	2 .18	3 .28+3	+ .574	+0 .32		2 .60	0 .70	+ .154	—5 .26
	2 .17	3 .41+3	+ .584	+0 .45		2 .70	0 .54	+ .054	—5 .42
11–35.	2 .16	3 .52+3	+ .594	+0 .56	Front cor. of dam	2 .754	2 .98+3.—0.02	.000	0 .00
	2 .15	4 .59+3	+ .604	+1 .63	Back " "	2 .750	0 .96+0	+ .004	—5 .00

TABLE 1—CONTINUED—DATA FOR FLOW OVER SPILLWAY DAM BELOW RIVERSIDE, ILL., DEC. 21, 1895.

B	Field Co-ordinates of Curve B.		Co-ordinates referred to zero = front corner of dam.		B'	Field Co-ordinates of Curve B'.		Co-ordinates referred to zero = front corner of dam.	
	Vertical.	Horizontal.				Vertical.	Horizontal.		
REMARKS.	y	x	Y	X	REMARKS	y	x	Y	X
	2'.754	2'.98+3'.—0.02	0'.000	0'.00	Did not touch....	2'.165	....	(+'.586	......
2–55 P. M.	3 .00	0 .22+0	— .246	—5 .74	3–13 P. M.....	2 .17	5'.09+3'	+ .584	+2'.13
	2 .90	0 .31	— .146	—5 .65		2 .18	3 .50+3	+ .574	+0 .54
	2 .80	0 .44	— .046	—5 .52		2 .19	3 .48+3	+ .564	+0 .52
2–57............	2 .70	0 .56	+ .054	—5 .40		2 ,20	3 .26+3	+ .554	+0 .30
	2 .60	0 .73	+ .154	—5 .23		2 .21	3 .14+3	+ .544	+0 .18
2–58............	2 .50	1 .04	+ .254	—4 .92	3–18............	2 .23	3 .02+3	+ .524	+0 .06
	2 .48	1 .19	+ .274	—4 .77		2 .25	2 .85+3	+ .504	—0 .11
	2 .47	1 .27	+ .284	—4 .69		2 .30	2 .65+3	+ .454	—0 .31
3–00............	2 .46	1 .45	+ .294	—4 .51		2 .35	2 .43+3	+ .404	—0 .53
	2 .45	1 .85+0	+ .304	—4 .11		2 .38	2 .29+3	+ .374	—0 .67
	2 .44	1 .30+3	+ .314	—1 .66	3–21............	2 .40	2 .18+3	+ .354	—0 .78
	2 .43	1 .64+3	+ .324	—1 .32		2 .35	2 .43+3	+ .404	—0 53
	2 .42	1 .95+3	+ .334	—1 .01		2 .40	2 .15+3	+ .354	—0 .81
	2 .41	2 .07+3	+ .344	—0 .89		2 .42	1 .96+3	+ .334	—1 .00
3–04............	2 .40	2 .17+3	+ .354	—0 .79		2 .43	1 .85+3	+ .324	—1 .11
	2 .39	2 .24+3	+ .364	—0 .72	3–27	2 .44	1 .07+3	+ .314	—1 .89
	2 .37	2 .36+3	+ .384	—0 .60		......	....	......	....
	2 .35	2 .44+3	+ .404	—0 .52		2 .45	0 .76+3	+ .304	—2 .20
	2 .32	2 .55+3	+ .434	—0 .41		......	....	......	......
	2 .30	2 .64+3	+ .454	—0 .32	3–29	2 .46	1 .51+0	+ .294	—4 .45
3–07............	2 .28	2 .75+3	+ .474	—0 .21		......	....	......	......
	2 .25	2 86+3	+ .504	—0 .10		2 .47	1 .28	+ .284	—4 .68
	2 .23	2 .97+3	+ .524	+0 .01		......	....	......	......
	2 .21	3 .13+3	+ .544	+0 .17	3–30	2 .50	1 .04	+.254	—4 .92
3–09.....	2 .20	3 .39+3	+ .554	+0 .43		......	....	......	......
	2 .19	3 .37+3	+ .564	+0 .41		2 .60	0 .73	+ .154	—5 .23
	2 .18	3 .70+3	+ .574	+0 .74		......	....	......	......
3–12............	2 .17	4 .98+3	+ .584	+1 .02	3–32	2 .80	0 .43	— .046	—5 .53
Did not touch...	(2 .165)	....	(+ .586)	.....		......	....	......	......

TABLE 1 CONTINUED—DATA FOR FLOW OVER SPILLWAY DAM BELOW RIVERSIDE, ILL., DEC. 21, 1895.

C	FIELD CO-ORDINATES OF CURVE C.		Co-ordinates referred to zero = front corner of dam.	
	Vertical.	Horizontal.		
REMARKS.	y	x	Y	X
3–32	2'.80	0'.43+0'	—'.046	—5'.53
	2 .60	0 .73	+ .154	—5 .23
3–33	2 .50	1 .05	+ .254	—4 .91
	2 .47	1 .31	+ .284	—4 .65
	2 .45	1 .81	+ .304	—4 .15
3–35	2 .46	1 .47	+ .294	—4 .49
	2 .45	1 .81	+ .304	—4 .15
3–37	2 .44	1 .41+3	+ .314	—1 .55
	2 .43	1 .87+3	+ .324	—1 .09
	2 .42	2 .06+3	+ .334	—0 .90
	2 .41	2 .13+3	+ .344	—0 .83
3–39	2 .40	2 .25+3	+ .354	—0 .71
	2 .39	2 .27+3	+ .364	—0 .69
	2 .37	2 .41+3	+ .384	—0 .55
	2 .35	2 .47+3	+ .404	—0 .49
	.....	....	......	......
3–41 P. M.	2 .30	2 .69+3	+ .454	—0 .27
	......	....	......	......
	2 .25	2 .93+3	+ .504	—0 .03
	2 .23	3 .01+3	+ .524	+0 .05
	......	....	......	......
	2 .21	3 .26+3	+ .544	+0 .30
	......	....	......	......
	2 .20	3 .32+3	+ .554	+0 .36
	......	....	......	......
	2 .19	3 .61+3	+ .564	+0 .65
	......	....	......	......
	2 .18	3 .91+3	+ .574	+0 .95
	......	....	......	......
Did not touch..	(2 .175)	....	(+ .576)	......
	......	....	......	......
	......	....	......	......

C′	FIELD CO-ORDINATES OF CURVE C′.		Co-ordinates referred to zero = front corner of dam.	
	Vertical.	Horizontal.		
REMARKS.	y	x	Y	X
Did not touch..	2'.175	....	(+'.576)	....
	2 .18	6'.19+3'	+ .574	+3'.23
	2 .18	5 .34+3	+ .574	+2 .38
	2 .19	3 .65+3	+ .564	+0 .69
	2 .20	3 .38+3	+ .554	+0 .42
3–49 P. M.	2 .21	3 .27+3	+ .544	+0 .31
	2 .21	3 .18+3	+ .544	+0 .22
	2 .23	3 .01+3	+ .524	+0 .05
	2 .25	2 .94+3	+ .504	—0 .02
	2 .30	2 .69+3	+ .454	—0 .27
	2 .35	2 .49+3	+ .404	—0 .47
	2 .37	2 .39+3	+ .384	—0 .57
	2 .39	2 .30+3	+ .364	—0 .66
	2 .40	2 .24+3	+ .354	—0 .72
3–53	2 .41	2 .14+3	+ .344	—0 .82
	2 .41	2 .16+3	+ .344	—0 .80
	......	....	......	......
	2 .42	2 .05+3	+ .334	—0 .91
	2 .42	2 .09+3	+ .334	—0 .87
	2 .43	1 .95+3	+ .324	—1 .01
3–55	2 .44	1 .77+3	+ .314	—1 .19
	2 .45	1 .22+3	+ .304	—1 .74
	2 .46	1 .47+0	+ .294	—4 .49
	2 .47	1 .34+0	+ .284	—4 .62
	2 .50	1 .06	+ .254	—4 .90
3–58	2 .60	0 .73	+ .154	—5 .23
	2 .70	0 .55	+ .054	—5 .41
	2 .80	0 .44	......	—5 .52
4–05	2 .90	0 .32	— .046	—5 .64
	......	....	......	......
Front cor. of dam	2 .754	2 .98+3.—0.02	.000	0 .00
Back " "	2 .750	0 .96+0	+ .004	+5 .00

TABLE II.

Co-ordinates of Average Curve, being average of the three average curves: AA', BB' and CC'.				Co-ordinates of Average Curve, being average of the three average curves: AA', BB' and CC'.		
Y	X	x		Y	X	x
+0'.587	+1 .5	7'.46 P.C		Tangent joining curves.	—2.0	3.96
.586+	+1 .4	7 .36			—2.1	3.86
.586	+1 .3	7 .26			—2.2	3.76
.585	+1 .2	7 .16			—2.3	3.66
.584	+1 .1	7 .06			—2.4	3.56
+0 .583	+1 .0	6 .96			—2.5	3.46
.582	+0 .9	6 .86			—2.6	3.36
.580	+0 .8	6 .76			—2.7	3.26
.578	+0 .7	6 .66			—2.8	3.16
.575	+0 .6	6 .56			—2.9	3.06
+0 .571	+0 .5	6 .46			—3.0	2.96
.565	+0 .4	6 .36			—3.1	2.86
.558	+0 .3	6 .26			—3.2	2.76
.549	+0 .2	6 .16			—3.3	2.66
.537	+0 .1	6 .06			—3.4	2.56
+0 .522	0 .0	5 .96			—3.5	2.46
.504	—0 .1	5 .86			—3.6	2.36
.483	—0 .2	5 .76			—3.7	2-26
.459	—0 .3	5 .66		+0 .308	—3.8	2.16 P. C.
.435	—0 .4	5 .56		....	—3.9	2.06
+0 .410	—0 .5	5 .46		+0 .307	—4.0	1.96
.388	—0 .6	5 .36		.307	—4.1	1.86
.370	—0 .7	5 .26		.306	—4.2	1.76
.355	—0 .8	5 .16		.305	—4.3	1.66
.343	—0 .9	5 .06		.302	—4.4	1.56
+0 .334	—1 .0	4 .96		+0 .299	—4.5	1.46
.327	—1 .1	4 .86		.293	—4.6	1.36
.321	—1 .2	4 .76		.285	—4.7	1.26
.318	—1 .3	4 .66		.274	—4.8	1.16
0+ .316	—1 .4	4 .56		.260	—4.9	1.06
.314	—1 .5	4 .46		+0 .240	—5.0	0.96
.314	—1 .6	4 .36		.213	—5.1	0.86
.313	—1 .7	4 .26		.175	—5.2	0.76
......	......	.....		.123	—5.3	0.66
.313	—1 .8	4 .16 P.C		+0 .057	—5.4	0.56
......	......	.....		—0 .022	—5.5	0.46
......	—1 .9	4 .06		—0 .106	—5.6	0.36
......	......	.....	Front cor. of dam	0 .000	0.0	5.96
......	......	....	Back " "	+0 .004	—5.0	0.96

DISCUSSION.

A broad crest dam, a view of which is shown in Fig. 27, constitutes a part of the various works of the sanitary district of Chicago. The length of the crest of the dam is 397 feet, its top width 5 feet, the down stream face vertical and the up stream face inclined at the

rate of one (1) horizontal to two (2) vertical. The body of the dam is made of natural cement concrete covered with a plaster of one part of Portland cement to two parts of sand, by volume. The top of crest is formed of "Joliet" limestone 1 foot thick and smoothly planed. A cross-section is shown in Fig. 21, showing also the elevation of the bottoms of the pools above and below the structure. Before the works of the sanitary district were undertaken, the Des Plaines river, at and below the site of the dam, divided its waters, especially in times of floods. A part of the waters flowed eastward through Chicago to Lake Michigan, and the rest found a westward course to the Illinois and Mississippi rivers. The purposes of the district required that the part of the waters which normally flowed through Chicago should as far as practicable, be diverted to the westward course. To this end an embankment was erected which would fully accomplish the purpose were it not that in its line the dam in question was placed. The crest of the dam is about eight (8) feet above the bed of the river opposite, and when the river has risen sufficiently water overflows it and flows to the lake. The location

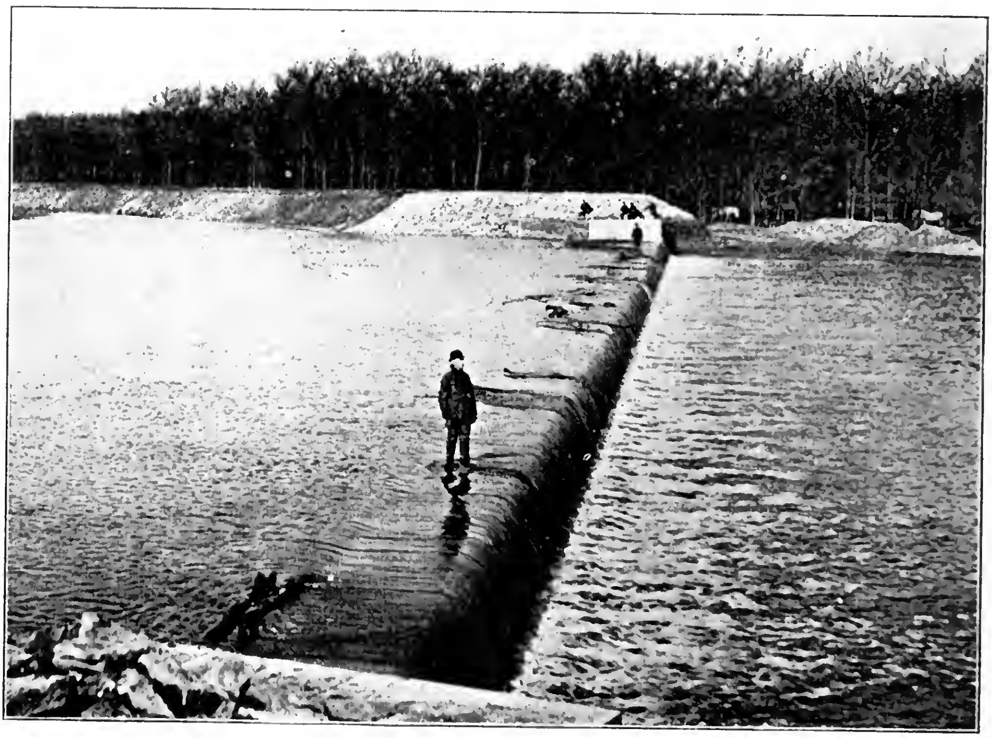

FIG. 27.

is on the left bank of the Des Plaines, about twelve miles west of central Chicago and one mile south of Riverside, a suburb on the line of the C., B. & Q. R. R.

The main works of the sanitary district lay in the valley of the Des Plaines, westward from the site of the dam, and to permit the construction of said work it was necessary to divert the river to the

north side of its valley for a distance of twenty miles west of the dam. The capacity of this new river, in conjunction with the flow that may take place over the dam is the basis of a hydraulic problem of much interest to the district. The physical conditions are such that there is no direct way of measuring the flow over the dam and consequently the experiments, of which this discussion is the subject, were made with a view to obtaining some desired information. A general scheme for making the measurements was devised and the task of developing its details and doing the field-work was entrusted to Mr. E. L. Cooley. His description of the apparatus and his method of doing the work forms a part of this paper. The average curve deduced by him—showing form of water surface over the crest of the dam—is used in what follows. The curve and the outline of the dam are referred to rectilinear co-ordinates in columns 1, 2 and 3 of table No. III, the origin being at up stream corner of the dam, and positive directions being measured up and to the right. The same are shown graphically in Figs. 28, 29 and 26. For purposes of illustration the vertical scale has been made larger in the last.

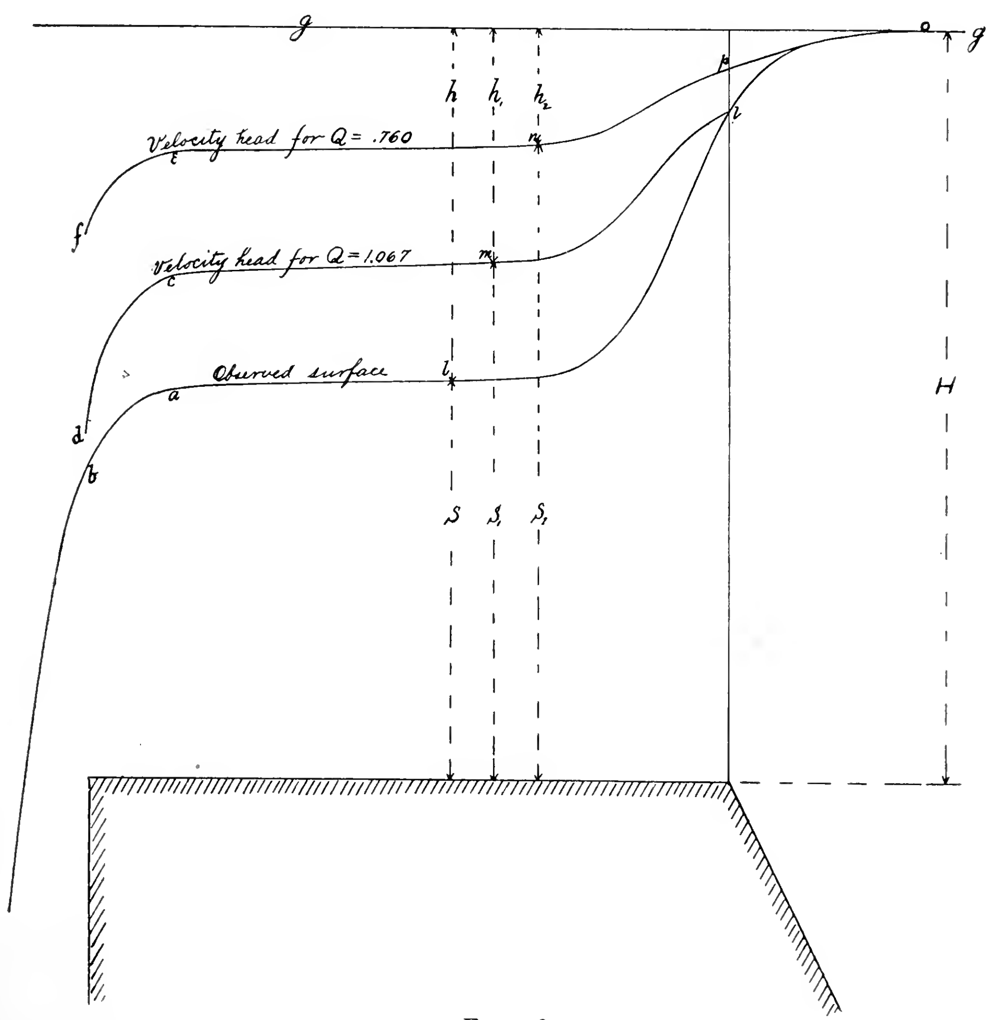

FIG. 28.

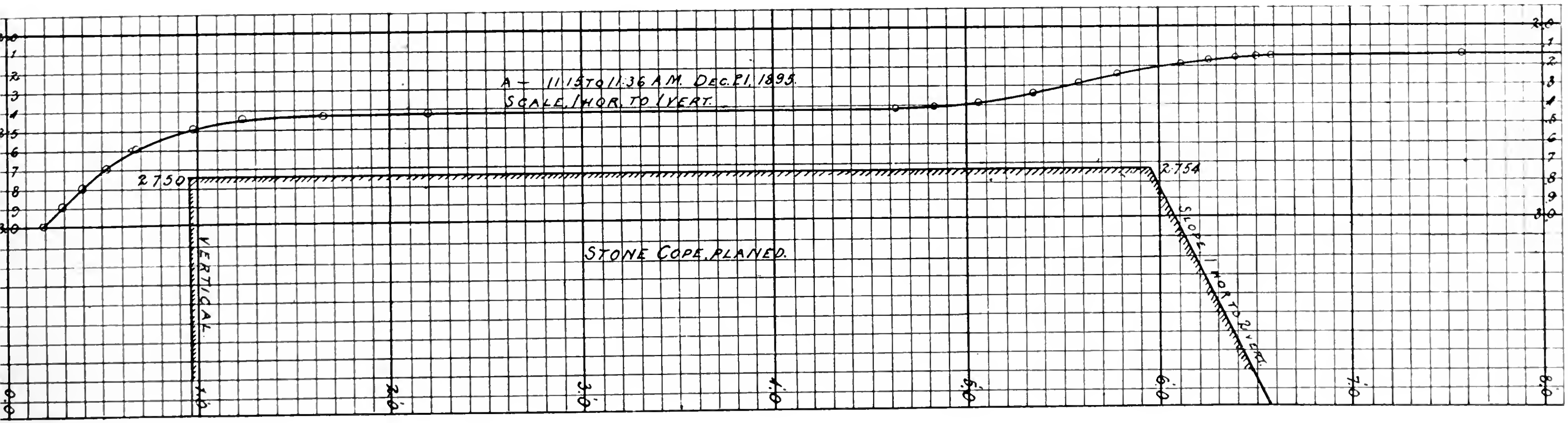
A – 11.15 TO 11.36 A.M. DEC. 21, 1895.
SCALE, 1 HOR. TO 1 VERT.
STONE COPE, PLANED.
VERTICAL.
SLOPE, 1 HOR. TO 2 VERT.
2.750
2.754

FIG. 29.

There has, in the past, been more or less discussion and contention by the authorities on hydraulics as to the form a water surface assumes in passing over the crest of a weir or dam. It will, perhaps, develop the merits of this new experiment, if the salient features of previous discussions be briefly presented.

James B. Francis records, in his "Lowell Hydraulic Experiments," page 136, a series of five experiments over a dam the crest of which measured 3 feet in the direction of the current, the length being 10 feet without end contractions. The disposition of the dam is shown in Figs. 30 and 31, taken from Plate No. XIV. of Mr.

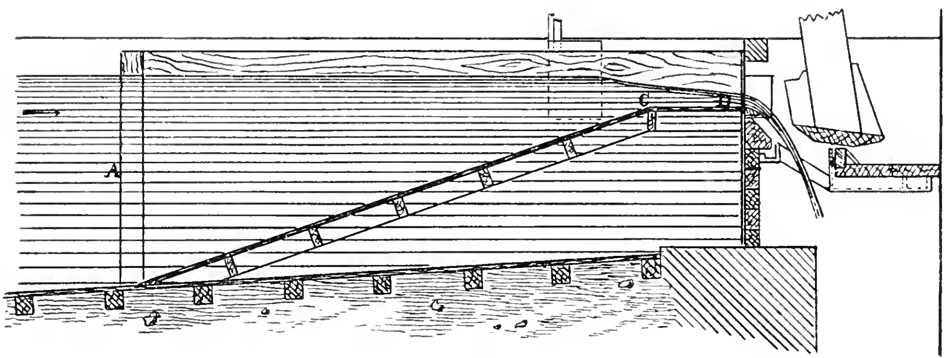

FIG. 30.

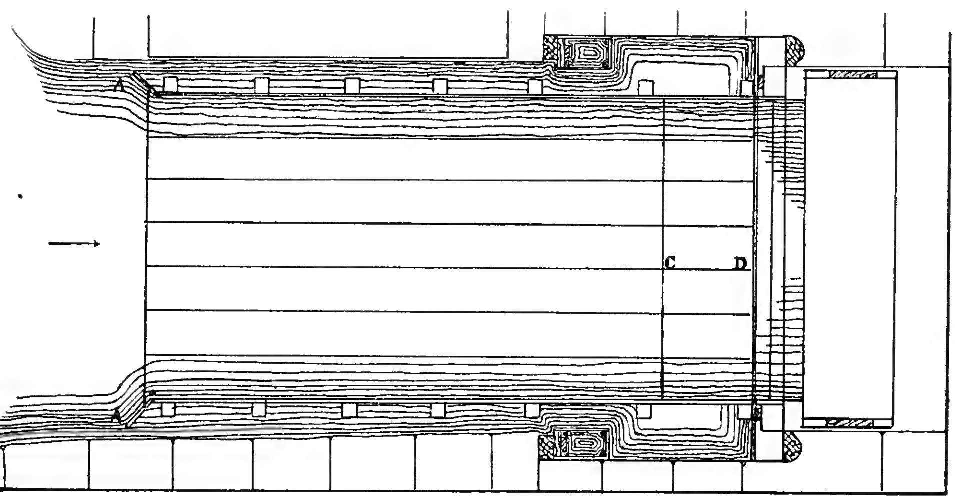

FIG. 31.

Francis' book. He does not discuss the form of water surface, contenting himself simply by stating the formula—

$$Q = 3.01208\ h^{1.53}$$

and tabulating his results, with comments, as follows:

"The form of the dam is represented by Figs. 11 and 12, Plate XIV. (Figs. 30 and 31 of this discussion); and the other apparatus was the same as that used for the experiments in Table XIII."*

---

* See "Lowell Hydraulic Experiments," by James P. Francis. Secs. 165 and 166 Miscellaneous Experiments on the Flow of Water, made at the Lower Docks in November, 1852.

"The end contraction was suppressed by making the canal leading to the overfall of the same width as the overfall itself. The water in the hook gauge boxes communicated only with the water contained in the spaces between the masonry and the woodwork forming the sides and bottom of the canal leading to the overfall; as there was a free communication between the water at A, Figs. 30 and 31, and that near the hook gauge boxes, and as the water between these places was sensibly at rest, we may consider that the height of the water was taken at A.

"In table XVI. (Table IV. of this article) these experiments are exhibited in sufficient detail to be intelligible.

"Columns 1 and 2 require no explanation.

"Column 3. The heights contained in this column are above the mean level of the crest of the dam, which was very nearly horizontal for a distance of 2.95 feet from C to D. These heights have not been corrected for the velocity of the water approaching the weir; indeed, from the manner in which they were observed, no correction was necessary.

"Column 4. The quantities in this column have been obtained in the manner described in the explanation of table XIII. (Art. 155.)

"Column 5. Quantity of water passing over the dam, calculated by the formula—

$$Q = 3.01208\ lh^{1.53}$$

"This formula was arrived at by trial of various powers of h, and was adopted as representing, the most nearly, the results of the five experiments in the table; it should be distinctly understood, however, that it is not applicable to depths much greater or less than in the experiments from which it is deduced. In April, 1852, the depth of water flowing over the dam at Lawrence was 10 feet; if the quantity then passing over the dam was computed by this formula, it is probable that it would be greatly in error."

TABLE NO. IV.

Time, from November 10th, 8 h. 57', P. M., to November 11th, 0 h, 11' A. M.
Temperature of the air at 10 h, 50', P. M., 34 50° Fahrenheit.
" " water " " " 41.75° "
The air calm.

1 Number of the experiment.	2 Length of the overfall. l	3 Mean height of the surface of the water in the hook gauge boxes, above the top of the horizontal crest of the dam; feet. h.	4 Quantity of water passing over the dam, as measured in the lock chamber, in cubic feet per second.	5 Quantity of water passing over the dam calculated by the formula, $Q = 3.01208\ l\ h^{1.53}$ In cubic feet per second.	6 Proportional difference, or the absolute difference of the quantities in columns 4 and 5, divided by the quantity in column 4.
89	9.995	0.58720	13 385	13.332	—0.0040
90	"	0.79035	20.892	21.005	+0.0054
91	"	0.97670	28.914	29.039	+0.0043
92	"	1.32520	46.183	46.317	+0.0029
93	"	1 63380	64 346	63.804	—0 0085

"Column 6. Proportional difference. It will be observed that the greatest proportional difference is 0.0085, or less than 1 per cent; we may therefore say, with confidence, that we can compute the flow of water over the Lawrence dam, when free from ice or other obstruction, for any depth not greater than 20 inches or less than 7 inches, without being liable to an error exceeding 1 per cent."

The useful part of these experiments in this connection is the coefficient of the formula.

Hamilton Smith, Jr., records in his work on Hydraulics, page 112, a measurement of form of water surface by Clemens Herschel, upon which he comments as follows:

"Mr. Clemens Herschel, hydraulic engineer of the Holyoke Water Power Company, has been kind enough to give us a section of the surface curve of the Connecticut river, as it passed over the Holyoke dam in 1883, in time of freshet. The form of the curve is shown by the following sketch" (Fig. 32):

"The height of the surface of the sheet above the crest, H_w, was 5.2, with $H = 7.27$; the horizontal length of the curve was about 50 feet. The dam is a long one, perhaps 1,200 feet, and the pool formed by it extends a distance of some two miles above the dam. The section was taken along the southerly abutment of the dam."

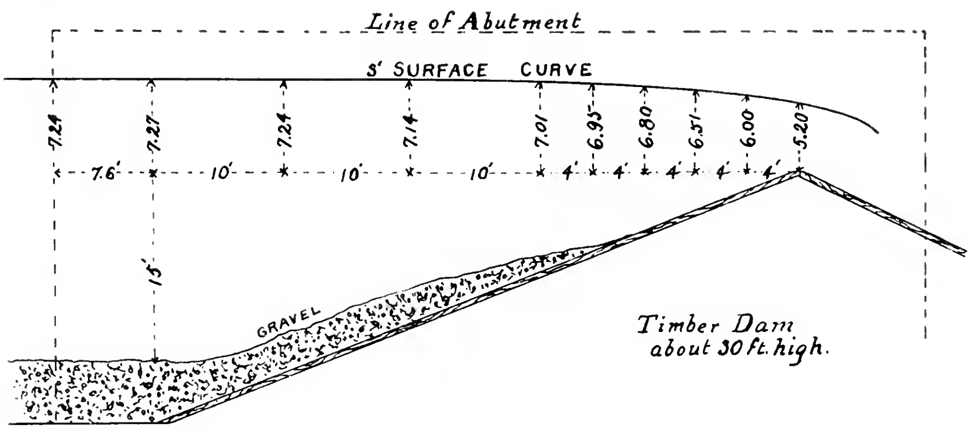

FIG 32.

Mr. Smith also records a set of experiments made by Messrs. Fteley and Stearns, on broad crest dams.

Broad and Rounded Crests.

"Lesbros experimented with both broad and rounded crests, but as Messrs. Fteley and Stearns have investigated the same subject more fully, we will avail ourselves of their experiments.†

"A fixed sharp-crested weir, made of hard pine, was placed across a canal 5 feet wide, end contractions hence being suppressed. The length of this canal was 6 feet; the inner depth below crest, or G, was 3.17 feet; H was measured at a point 6 feet above the weir, near the bottom of the channel. A constant flow of water was admitted into the canal, and H was determined, for the flow over the sharp

†Transactions Am. Soc. of C. E., 1883, pages 86-101.

crest; a false piece of wood of the desired width was then slid into place on the lower side of the fixed crest and drawn into close contact by several fastenings; the height of the water in the canal, or H', was then measured, Q remaining constant. The quantity of flow into the canal was then increased and another set of comparisons made, Q being always constant for each set of comparisons. The upper sides of the false or broad crests were horizontal; the total widths of these crests were respectively 2, 3, 4, 6 and 10 inches.

"In the following table are given the results of these comparisons, except for three experiments, which were thought to be faulty."

TABLE No. V.

"Fteley and Stearns—Table LIV—Comparison of Heads with Weirs having sharp and broad crests, Q being constant for each comparison.

CREST = 10″.

H.	*H'*	*H—H'.*	*C.* ($Q=cH'^{3/2}$)
.1120	.1352	—.0232	2.649
.1153	.1394	—.0241	2.643
.1449	.1712	— 0263	2.685
.2422	.2872	—.0450	2.625
.2877	.3403	—.0526	2.627
.2924	.3449	—.0525	2.634
.4224	.4907	—.0683	2.682
.4634	.5350	—.0716	2.702
.5155	.5861	—.0706	2.765
.5544	.6307	—.0763	2.763
.6017	.6794	—.0777	2.793
.6581	.7323	—.0742	2.860
.7061	.7776	—.0715	2.906
.7561	.8222	—.0661	2.966
.8129	.8752	—.0623	3.011

"*N. B.*—The last column given in this table is not in Hamilton Smith's Hydraulics."

Table No. V contains the results applying to a crest ten (10) inches broad. The co-efficients are given to apply in the formula—

$$Q = cH^{3/2}.$$

No attention is paid to the form of surface over the crest.

The article Hydro-mechanics in the ninth edition of the "Encyclopedia Britannica," signed with the initials W. C. U. (W. Cawthorne Unwin), contains the following:

Weir With a Broad Sloping Crest.—"Suppose a weir formed with a broad crest, so shaped that the stream flowing over it has a movement sensibly rectilinear and uniform. Fig. 33. Let the inner edge be so rounded as to prevent a crest contraction. Consider a filament $a\ a'$, the point a being so far back from the weir that the velocity of approach is negligible. Let O O be the surface level in the reservoir, and let a be at a height, h'', below OO, and h' above a'. Let h be the distance from OO to the weir crest, and e the thickness of the stream upon it. Neglecting atmospheric pressure, which has no influence, the pressure at a is Gh″ and at a' it is Gz. If v be the velocity at a'—

$$\frac{v^2}{g} = h' + h'' - z = h - e,\ Q = be\sqrt{2g(h-e)}.$$

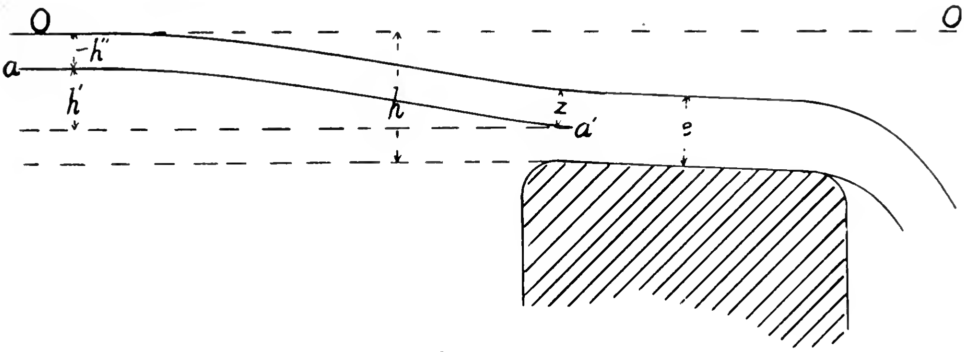

Fig. 33.

Theory does not furnish a value for e, but $Q = o$, for $e = o$ and for $e = h$. Q, therefore, has a maximum for a value of e between o and h, obtained by equating $\frac{dQ}{de}$ to o. This gives $e = \frac{2}{3}h$, and, inserting value, $Q = 0.385$ bh $\sqrt{2gh}$, as a maximum value of the discharge with the conditions assigned. Experiment shows that the actual discharge is very approximately equal to this maximum.

In the above discussion G is understood to designate the specific weight of water, and b the breadth, or, as often expressed, the "length," of the weir.

The formula stated herein was derived independently by Jos. P. Frizell. (See Engineering News, Sept. 29, 1892, and Jan. 31, 1895.)

Trautwine, in his Hand Book for Engineers, records the case of Clegg's dam, in Cape Fear river, N. C., from measurements by Ellwood Morris, C. E. The record is shown in Fig. 34. This involves solely the form of water surface.

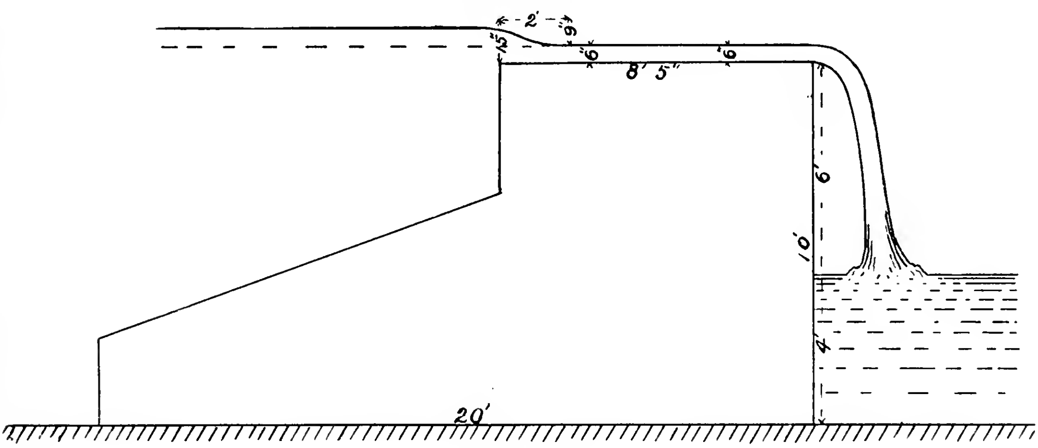

Fig. 34.

Engineering News of Jan. 31, 1895, contains some extended discussions of the matter by Messrs. Edward N. Pike, N. Werenskiold and Jos. P. Frizell. Mr. Werenskiold advances Fig. 35, and enters into a mathematical discussion, Mr. Frizell dissenting from the hypotheses on which it is based.

This brief summary may well be closed with the following quotation from Mr. Frizell, containing in the last discussion cited: "It is manifest * * * that the velocity of the water, at any point

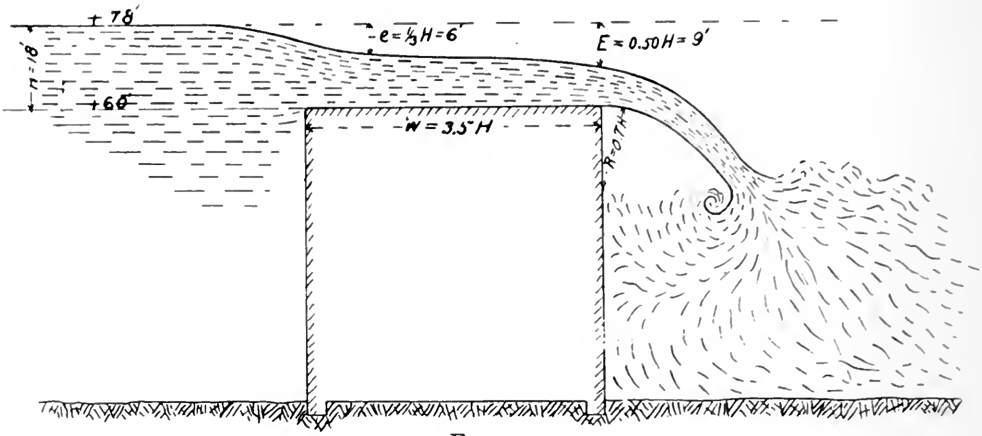

FIG. 35.

on the level part of the weir, friction not considered, can not be greater or less than that due to the descent of the surface at the same point."

Referring to Fig. 28, and following the observed curve of water surface, he means, it is assumed, that the mean velocity of flow through the vertical cross-section at *l*, "friction not considered," can not be greater or less than that due to a head *gl*, which is the vertical distance the surface descends at the point *l*. And "*l*" may be any point on the curve between *k* and *b*. Expressed in mathemetical terms the same idea will be stated as follows:

$$Wh = \frac{W}{2g}(v_1^2 - v_1^2) + f(R) \ldots\ldots (1)$$

In which v_1 is the mean velocity through any vertical section as at *k* and *v* the mean velocity through any other vertical section, as at *l* or *b*.

W is the weight of the water flowing through either section in a unit of time.

h is the descent of surface or head lost between *k* and *l* or *b*, as the case may be.

g is the force of gravity, taken to be 32.16.

f (R) is the work done in overcoming the resistance to flow between the two sections, which Mr. Frizell has characterized as "friction not considered."

If v_1 be applied to the point o where the surface is horizontal above the dam then $v_1 = 0$ and

$$Wh = \frac{Wv^2}{2g} + f(R) \ldots\ldots (2)$$

or

$$h = \frac{v^2}{2g} + f^1(R) \ldots\ldots (3)$$

Particular attention is called to the expression: f^1 (R). It will be noticed in the discussions above referred to, that this term has been neglected. This fact has led to the deduction that H—h, in the Fig. 28 = ⅓H. The particular experiment in hand shows H—h = 0.587—0.313 = 0.274 = 0.0466 H. And the Cape Fear river case shows H—h = 0.75 = ⅗ H. Perhaps these discrepancies may be reconciled by a proper consideration of the "friction not considered," or the value of *f* (R).

If the discharge over the dam at the time of the experiments in question was known, then it would be easy to calculate the mean

velocity through all vertical sections between k and b, Fig. 28. And since equation (3) may be written in the form—

$$f'(R) = h - \frac{v^2}{2g} \qquad (4)$$

it would be easy, since both terms of the last member of (4) would be known, to determine not only the total head consumed by resistances to flow to any point l, but also the loss from the same cause between any two points k and l.

Let it be assumed, for the present, that the term f' (R) may be neglected, then (3) becomes:

$$h = \frac{v^2}{2g} \qquad (5)$$

If h be measured at observed point k, which is just as good as any other point under the hypothesis, then the mean velocity in the vertical section at k can be computed, and likewise the discharge. For the case in hand the discharge is found to be 1.067 cubic feet per second for each lineal foot of the dam. This discharge being the same for all sections, the velocity in all sections between k and b can be readily computed. The heads due to these velocities, as h in the Fig. 28, can in turn be computed and can be entered in the Fig. at m similarly for other points, so that the curve $k\ m\ d$ may be developed, which may be termed the curve for velocity head due to the discharge: $Q = 1.067$. Column 4 of table No. III. contains the values for s_1 for this curve. According to the hypothesis, the curves $k\ m\ d$ add $k\ l\ b$ should coincide, but, failing to do so, the hypothesis is shown to be wrong. Other considerations prove the same thing. Column 5 of table No. III gives the differences between s and s_1 in passing from k to b. Now, suppose that the hypothesis made be true for points between o and k (for the column of water has not entered over the crest of the dam until it has reached k), then the differences s_1—s may be taken to represent the values of f' (R) from point to point between k and b. That is, the differences s_1—s are the losses of head irrecoverably lost in overcoming the resistances to flow. However, in passing from a to b the observed loss of head is found not to be enough to account for the increase of kinetic energy between the points. It really requires a loss of head equal to the vertical distances between c and d. The result is absurd. The same conclusion is reached by considering that ca is greater, much greater, than db, which fact indicates that, instead of the resistances to flow consuming head, they really create it. This, of course, cannot be. If the discharge had been smaller, then the velocities in sections at a and b would have been smaller, and the increase of kinetic energy between the two smaller and more nearly consistent with the loss of head between a and b.

The hypothesis above made has been thrown away, and approximation employed to establish a velocity head curve giving consistent losses of resistance head as the water passes over the dam. A value for head-producing velocity at section k has been assumed equal to $tp = 0.033$. From this as a basis the curve $p\ n\ f$ has been computed in the same manner as was $k\ m\ d$. Column 6 of the table No. III contains the values of s_2 and column 7 the values s_2—s. It will be

TABLE III.

Co-ordinates of observed water surface and crest of dam.			Co-ordinates of velocity head curve for Q = 1.067.		Co-ordinates of velocity head curve for Q = 0.760.	
1	2	3	4	5	6	7
Abscissæ in feet.	Ordinates of observed curve values of s in feet.	Ordinates of crest of dam.	Values of s_1 in feet.	Values of $s_1 - s$.	Values of s_2 in feet.	Values of $s_2 - s$.
+1.5	+0.587	......	......	......	......	......
1.4	0.586	......	......	......	......	......
1.3	0.586	......	......	......	......	......
1.2	0.585	......	......	......	......	......
1.1	0.584	......	......	......	......	......
1.0	0.583	......	......	......	......	......
0.9	0.582	......	......	......	......	......
0.8	0.580	......	......	......	......	......
0.7	0.578	......	......	......	......	......
0.6	0.575	......	......	......	......	......
0.5	0.571	—1.000	......	......	......	......
0.4	0.565	......	......	......	......	......
0.3	0.558	......	......	......	......	......
0.2	0.549	......	......	......	......	......
0.1	0.537	......	......	......	......	......
0.0	0.522	0.000	0.522	0.000	0.554	0.032
—0.1	0.504	......	0.517	0.013	0.552	0.048
0.2	0.483	......	0.511	0.028	0.549	0.066
0.3	0.459	......	0.503	0.044	0.544	0.085
0.4	0.435	......	0.493	0.058	0.540	0.105
0.5	0.410	......	0.482	0.072	0 535	0.125
0.6	0.388	......	0.469	0.081	0.527	0.139
0.7	0.370	......	0.457	0.087	0 521	0.151
0.8	0.355	......	0.446	0.091	0.515	0.160
0 9	0.343	......	0.436	0.093	0.510	0.167
1.0	0.334	......	0.427	0.093	0.506	0.172
1.1	0.327	......	0.420	0.093	0.503	0.176
1.2	0.321	......	0.414	0.093	0.499	0.178
1.3	0.318	......	0.411	0.093	0.498	0.180
1.4	0.316	......	0.409	0.093	0.497	0.181
1.5	0.314	......	0.406	0.092	0.495	0.181
1.6	0.314	......	0.405	0.091	0.495	0.181
1.7	0.313	......	0.404	0.091	0.494	0.181
1.8	0.313	......	0.404	0.091	0.494	0.181
3.8	0.308	......	0.397	0.089	0.491	0.183
3.9	......	......	......	......	......	......
4.0	0.307	......	0.396	0.089	0.490	0.183
4.1	0.307	......	0.396	0.089	0.490	0.183
4.2	0.306	......	0.394	0.088	0.489	0.183
4.3	0.305	......	0.393	0.088	0.489	0.184
4.4	0.302	......	0.389	0.087	0.487	0.185
4.5	0.299	......	0.385	0.086	0.485	0.186
4.6	0.293	......	0.375	0.082	0.480	0.187
4.7	0.285	......	0.363	0.078	0.473	0.188
4.8	0.274	......	0.344	0.070	0.464	0.190
4.9	0.260	......	0.317	0.057	0.450	0.190
5.0	0.240	+0.064	0.269	0.029	0.426	0.188
5.1	0.213	......	......	......	......	......
5.2	0.175	......	......	......	......	......
5.3	0.123	......	......	......	......	......
5.4	+0.057	......	......	......	......	......
5.5	—0.022	......	......	......	......	......
5.6	—0.106	......	......	......	......	......

NOTE—All co-ordinates originate at up-stream corner of dam.

observed that the latter values constantly increase as f is approached, excepting for the point f itself, where the diminution is so small that it may be neglected or attributed to error of observation. The rate of increase of $s_2—s$ is, however, quite small, the rate between n and e is not materially different from that between e and f, though, perhaps, it should be somewhat less. The inference is that the discharge Q = 0.760 cu. ft. pr. sec., corresponding to the curve pnf, is none too small, and doubtless very near correct, providing, of course, that the data is correct.

The large values $s_2—s$, for f'(R) are remarkable. They form about two-thirds of the total head lost to a. They are to a certain extent, however, consistent with the fact that H + h = 0.466 of H instead of 1-3 H, as called for by the formulae used in previous discussions of the subject.

This new experiment affords an avenue by way of which the data for the Cape Fear river case may be reconciled with preconceived notions. Mr. Frizell seems to doubt the accuracy of the data (Engineering News, Jan. 31, 1895). But if the values of f' (R) were greater for that case than for the experiments in hand, then it may easily be seen that the depth in the weir or dam could be two-fifths instead of two-thirds of the total head H = 15 inches.

Let it be assumed that the discharge over the Des Plaines dam be 0.760 cu. ft. per sec., as called for by the curve pnf, Fig 28. It will then be useful to compare the co-efficients derived for the formula

$$Q = ch^{3h}$$

from the several experiments herein-above referred to. The following table, No. VI, contains the comparison:

TABLE VI.

Francis.		Fteley and Stearns.		Desplaines River.		Union and Frizell.	
h Head in Feet.	c	h Head in Feet.	c	h Head in Feet.	c	h Head in Feet.	c
0.587	3.01	0.1352	2.649	0.587	1.69	Not definitely stated.	......
0.790	3.01	0.1394	2.643	......	......		......
0.977	3.01	0.1712	2.685	......	......		......
1.325	3.01	0.2872	2.625	......	......		......
1.634	3.01	0.3403	2.627	......	......		......
......	......	0.3449	2.634	......	......		......
......	......	0.4907	2.682	......	......		......
......	......	0.5350	2.702	......	......		3.09
......	......	0.5861	2.765	......	......		......
......	......	0.6307	2.763	......	......		......
......	......	0.6794	2.793	......	......		......
......	......	0.7323	2.860	......	......		......
......	......	0.7776	2.906	......	......		......
......	......	0.8222	2.966	......	......		......
......	......	0.8752	3.011	......	......		......

Francis gives a constant value for c, approximating closely to that deduced by Unwin and Frizell.

Fteley and Stearns establish a varying value for c, all values being generally smaller than that given by Francis.

The experiments under discussion give the remarkably low value of 1.69, and it is highly probable that the value of c for the Cape Fear river case would be still smaller.

The Unwin and Frizell deduction establishes a maximum possible value for c when resistances to flow are totally neglected.

Some explanation for these variations is desirable. Referring to Fig. 28, it will be noted that the greater part of the loss of head due to resistances to flow occurs immediately after the water has entered the crest, and may therefore be attributed to what is commonly called "contraction." A comparison of the forms of the several crests may therefore be useful.

The Unwin and Frizell crest, which gives the highest value for c, is assumed to be properly rounded at its upstream end so as to eliminate the resistances following "contraction" and frictional and other resistances are entirely neglected.

The Francis crest (Fig. 30) is approached by a long inclined bottom, having a slope approximately three (3) horizontal to one (1) vertical. His value of c is next in the list.

The Des Plaines river crest (Fig. 28) has a much steeper crest, the up-stream surface of dam having a slope of one-half ($\frac{1}{2}$) horizontal to one (1) vertical.

The Cape Fear river case (Fig. 34) has a vertical up-stream face.

Taking these statements in their order, it is reasonable to assume that the losses due to "contraction" would increase from one to the other, and the values of c become smaller, which is actually the case, except for the Cape Fear river dam, and highly probable for it.

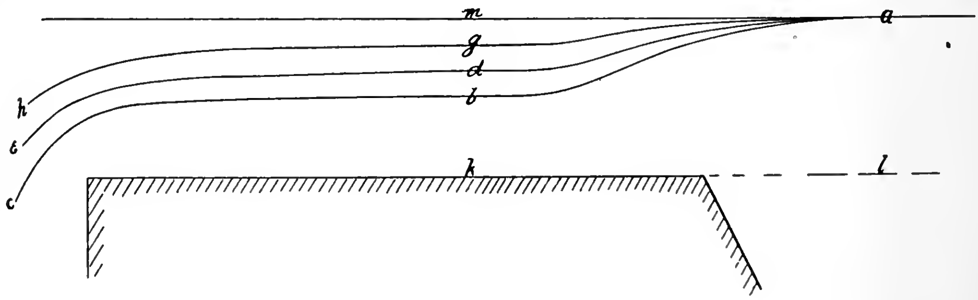

Fig. 36.

The low value of c for the Des Plaines river dam may be rationalized in still another way. Referring to Fig. 36, let $a\ b\ c$ be the observed curve, such that $b\ k$ stands in the relation to $a\ l$ as 0.313 stands to 0.587. Now, according to Unwin and Frizell the curve should be $a\ d\ e$, such that $d\ k$ stands in relation to $a\ l$ as 2 does to 3. In this case all of the head $m\ d$ would be used in creating velocity and would be the maximum head that could be possibly so used when the total head is $a\ l$. Now, the discharge for the curve $a\ b\ c$ must be smaller than would have been the case if the curve $a\ d\ e$ had obtained, and in a degree such that the mean velocity through $b\ k$ shall be less than would have been the case through $d\ k$. And, also, the head m which was actually used in creating velocity

through *b k*, must be less than *m d*. The value assigned to *m g* in table No. III, where Q=0.760 cu. ft. per sec. is 0.097, whereas *m d* is 0.196 and *m b* 0.274. It necessarily follows that the value of *c* must grow less, as *b k* is less than *d k*, and therefore the value of *c* for the Cape Fear river case must be less than for the Des Plaines river case.

It follows also that the exact form of the curve *a b c* is dependent on the nature and extent of the resistances to flow over the crest of the dam, and therefore, that no definite rule can be stated as to the ratio that will exist between *b k* and *a l* in any particular case.

It might be inferred that the magnitude of the values of *c*. table No. VI, given by the experiments of Fteley and Stearns, discredit the remarkably low value derived from the Des Plaines river case. Such a conclusion does not follow, for when equivalent heads are considered, the length of crest for the latter case is very much greater than for the former. Furthermore, if the relative dimensions, generally speaking, be the same for the two cases, then in the former the velocities involved will be much less than for the latter, and consequently higher values of *c* may be expected for the former.

Summarizing the indications of the new experiment, it appears:

(1) That the assumptions which have neglected resistances to flow over the crest have but limited justifications in practical cases, and that computations based on these assumptions are apt to be erroneous.

(2) That when the breadth of crest is considerable, wide variations of flow for a given head may be expected, depending on the form of the crest and the frictional resistances offered to flow.

(3) No definite rule can be established governing the relations of the several depths on the crest or describing the form of surface curve, because resistances to flow govern.

(4) That some broad-crest dams permit a much less flow for a given head than was formerly supposed.

THOS. T. JOHNSTON.

IV

LAKES AND ATLANTIC WATERWAY.

Memorandum in Regard to Certain Profiles Designed to Exhibit the Ruling Points.

Compiled by the Publication Committee from the Records of the Sanitary District of Chicago.

The several profiles herewith are designed to show the shallows and obstructions along natural water routes from Chicago and Duluth in the West to Quebec and New York in the East, via the several great lakes and their connecting waters, the St. Lawrence River and the Champlain-Hudson Valley, all referred to mean tide at New York. The scale adopted is 10 feet vertical to each centimeter and one mile per centimeter horizontal.

Plate 37 refers to the connecting waters above Lake Ontario. On this is shown the thalweg of the St. Mary's River between Lakes Superior and Michigan, the location of the rocks and the cuttings made in the river in the improvement of the same; the Straits of Mackinac, connecting Lakes Michigan and Huron; the passage between Lakes Huron and Erie via the St. Clair River, Lake St. Clair and the Detroit River, showing the several cuttings made in improving the same; also the profile of the Niagara River between Lakes Erie and Ontario, of the Welland Canal, and of the proposed Niagara Ship Canal, on the American side, via the Lockport route.

Plate 38 shows the St. Lawrence River from Lake Ontario, at Ontario, at Cape Vincent, to deep water at Quebec. The profile shows the several rapids between Ogdensburg and Montreal, the canal system overcoming the same and the ship channel dredged through the shoals of the St. Lawrence between Montreal and Quebec.

Plate 39 shows the Champlain-Hudson Valley route from the St. Lawrence at Caughnawaga via the projected Caughnawaga Canal to the Richelieu River at St. Johns, thence the Richelieu River to Rouses Point, thence Lake Champlain to Whitehall, thence the Champlain-Hudson divide to St. Edwards, thence the Upper Hudson to Troy dam, thence the tidal Hudson from Troy to New York and out to sea by Sandy Hook. The existing Chambly Canal from St. Johns to Chambly and the Champlain Canal from Whitehall to West Troy and by the Erie to Albany are also shown.

Plate 40 on one-fifth the scale gives a general profile from Chicago and Duluth-Superior to New York and Montreal and shows the relation of the lakes, rivers and divides as a whole.

These profiles were prepared primarily with a view of bringing together the relation of elevations, slopes and depths for the purpose of discussing lake levels. The series includes charts showing relative lake fluctuations for a term of years. The data have been

gathered from various sources, some of which are nearly thirty years old, and represent much labor in adjustment and compilation. The results are to be regarded as the best obtainable from existing material. The profiles are, however, to be regarded as trial profiles, subject to revision in the light of new and more extended information which may come to hand, especially on portions of the St. Lawrence River and the Champlain-Hudson route.

The Champlain-Hudson profile was not part of the original set, but in gathering data the material for this was brought to light and has been delineated as an incident of the investigation.

On the profiles are indicated the high and low water lines and the elevation of the same, along with mean elevations, are indicated in tables. The high water used is the high water of 1838 and its equivalent, and the low water that of 1847, known as the Chicago datum, or the equivalent low water as nearly as may be.

As part of the series, the Sanitary District is preparing a profile by the Desplaines and Illinois Rivers to the Mississippi, and down the Mississippi to Cairo, on which will be shown the Hennepin Canal and the lower courses of the Upper Mississippi and the Missouri; and also a general profile from the lakes to the gulf, all on the scale of the Lake-Seaboard profiles.

The value of these profiles in discussing the subject of water routes through the lakes and thence to the sea is apparent, and the great labor and time required to bring together the scattered items of information is doubtless the reason why it has not heretofore been attempted on any basis of accuracy. In regard to the purely American route from Lake Ontario by the Mohawk Valley to the Hudson, no data which would warrant a thalweg profile except of the most proximate character and on a very small scale has been found, and the information is positive that no surveys have yet been made which would warrant such profiles over more than a small fraction of the line. The same may be said of the purely Canadian route from Georgian Bay by the French River, Lake Nipissing and the Ottawa River, except that an actual profile of water and land surfaces has been made, proximate in character and depending in part on reconnoissances. A series of profiles designed to be exhaustive of the question of routes should show existing waterways and other lines that have been projected. These have not been compiled, as the Sanitary District has not felt called upon to pursue the investigation further than warranted by questions of lake level and recording other material incidentally brought together.

No attempt will be made to discuss these profiles at this time. The data is very fully recorded on the sheets. The essential facts in regard to the area of the lakes, watersheds, discharge of rivers, etc., were published and discussed at length by the Western Society of Engineers in 1888 and published in the Journal of the Association of Engineering Societies for 1889. Little new material has been gathered since, the principal items being a few discharge measurements on the Niagara River in the vicinity of Buffalo in 1891-2 (see report Chief Engineers, U. S. A., 1893, p. 4364), and the

discussion of the effects of a gale on the level of Lake Erie by Wm. T. Blunt (see report Chief Engineers, U. S. A., 1894, p. 3431). Doubtless all this primary data will be finally recompiled from the latest charts and maps, and it is not thought expedient to repeat the old compilations in this connection. Much interesting discussion has occurred within the last two years in regard to lake levels and lake regulations, and the essential features of this have been printed in the Proceedings of the Cleveland Deep Waterways Association, published in November, 1895.

It is sufficient to here point out that the several profiles show the entire feasibility of a waterway as deep as may be useful between the several lakes and extending by the St. Lawrence and by the Champlain-Hudson Valley to the Seaboard. In fact, the channels providing for a depth of 20 feet at ordinary stages, including the new lock at Sault Ste. Marie, will be opened between Chicago, Duluth and Buffalo in 1896-7, and the St. Lawrence canals will be opened for fourteen feet at the same time, giving that depth between Lake Erie and Montreal, and the Ship Channel between Montreal and Quebec for 27½ feet was opened several years ago. In 1870-5 projects were made for a 12-foot route from the St. Lawrence via Lake Champlain to deep water in the Hudson, and the Hudson is now undergoing improvement for 12 feet from Troy Dam southward. These earlier investigations indicate the feasibility of the larger requirements of the present. It is apparent from the profiles that less work is required to extend ship navigation up the Hudson to Troy Dam than has already been done on the St. Lawrence below Montreal.

Alternative routes and their possibilities must await very comprehensive surveys in order to test their availability in comparison with the routes shown on these profiles. It is in every way desirable that such examinations should be made, as well as comprehensive data collected in regard to the physics of the lake basins before any final conclusions are reached.

TOPICAL DISCUSSIONS.

I

HYDRAULIC CEMENT.

The following articles have been received from members of the Society and others in response to a request for information on this subject. A circular was issued December 15 asking for discussions as to: 1. Relative qualities of the several Portland and natural cements at present in general use. 2. The extent to which the testing of cements is useful in connection with various classes of work. 3. What nature of testing is suitable. 4. The essential points which should be covered in specifications as to testing cements. 5. The influence of the amount of water used in forming pastes and mortar. 6. How the several cement mortars are affected by cold, both in laboratory and in practical work. 7. How mortars are affected by tempering. 8. What specifications should require as to mortar and mortar mixing. 9. How cement mortars are affected by different kinds of sand. 10. What extent cement mortar plasters can be relied upon to adhere to cement mortar concretes, especially when Portland cement is used for plaster and natural cement for concrete.

Further discussion of this subject is earnestly requested from both members and others.

THE PUBLICATION COMMITTEE.

CEMENT AND ITS USES.

By Alfred Noble, M. W. S. E.

The crushing strength of a mass of masonry, if built of stone of fairly good quality, is less than that of stone; the mortar joint is the weaker place; as the strength of this depends upon the materials of which it is composed, their character should be known; passing for the present the effect of varying the character of the sand the inquiry is narrowed to the question of the character of the cement.

When a high and uniform degree of strength is required in the masonry a high grade of cement is indispensable and this condition will usually involve the use of Portland cement. It is now possible to buy Portland cement of such uniform excellence that little risk is taken in using it without a test; this character, however, has only been secured by constantly definite requirements made by engineers and it can hardly be doubted that the quality of material manufactured would deteriorate if such requirements were dropped.

When a moderate degree of strength is sufficient economy requires that the mortar should be as little above the necessary strength as practicable; this is adjusted by adopting the proper proportions of cement and cheaper inert material, ordinarily sand, but the proportions must be so fixed that the strength of the mortar shall not fall

below a determined minimum. If the quality of the cement is variable these proportions must be fixed with regard to the poorest; if the variation is great the use of such cement will not be economical and in any extensive work the expense incurred in testing will be wisely made. In work of the character now under consideration natural cements will be used ordinarily and on account of the variable character of the rock from which they are made, as well as imperfect or careless manufacture, even a moderate standard cannot be assured without constant testing; in general, it must be said that testing is necessary to exclude not only cement of low grade, but cement of dangerous quality which will cause disintegration of the mortars into which it enters.

The tests of cement usually recommended relate to the fineness, hydraulicity, expansion, time required for setting and strength. It is generally admitted that the capacity of a cement to carry sand increases with its fineness or, in other words, the more finely the cement is ground, the greater the strength of the mortar when composed partly of sand. About twenty years ago the writer had been led to question this as regards Louisville cement and made a number of tests. A quantity of cement was screened through a screen of 80 wires per lineal inch and both the sifted cement and the coarse particles were retained in separate lots. Several mixtures were then prepared containing definite proportions of the sifted cement and the coarse screenings and briquettes for tensile test were made from them, both of neat cement and of mortars containing nominally equal parts by volume of cement and sand. The briquettes were kept in water and broken at the age of six months. The results are given in table VII, of the appendix; each result is the mean of five tests.

These tests confirmed the prevailing opinion that mortars of neat cement are stronger with a considerable proportion of coarse particles; it was not until the proportion became greater than 30 per cent that the strength of the mortars was less than when made wholly of screened cement. As regards Portland cement, it had been ascertained long before that time that a coarsely ground cement would give a stronger mortar when mixed neat.

With the mortars containing sand of volume approximately equal to the volume of cement the result was somewhat similar, except—and the difference is important—that the maximum strength was reached with a smaller proportion of screenings. The decrease in strength, with the further addition of screenings, was more rapid. The maximum strength was given when the cement mixture contained 10 per cent of screenings; when the proportion was increased to 20 per cent the strength of the mortar was a little less than when only sifted cement was used; the indication was that strength equal to that with sifted cement would have been given with cement containing 15 per cent of screenings, and it might be further inferred that if the proportion of sand were doubled the sifted cement would give the strongest mortar.

Nothing is more injudicious, however, than to rush to a conclusion from insufficient data. The writer was not satisfied with

these results and when opportunity was presented a few years later they were repeated with some variations in the proportions of sand and with the use of a sieve of 100 wires per lineal inch in lieu of the No. 80 screen first used. The results are given in table VIII of the appendix. Each result is the mean of ten tests.

These results show no marked increase or marked change in the strength of neat cement mortars as the proportion of screenings is increased to 40 per cent.

With proportions by volume of cement 1 : sand 1 1-3, the strength of the mortars was greater when the cement contained 10 per cent or even 20 per cent of coarse particles and was little diminished when the proportion of coarse particles was increased to 30 per cent.

With mortars of cement 1 : sand 2 2-3 by volume, the reduction of strength was not great if the cement contained 10 per cent of coarse particles and was only reduced about 10 per cent when the proportion of coarse particles in the cement was 20 per cent.

The results accord fairly well with the first series, particularly if account be taken of the fact that in the first series the cement was screened with a No. 80 sieve and in the second with a No. 100. They indicated that the requirement as to fineness should depend upon the proportion of sand to be used in the mortar, if 1:1 the presence of 20 per cent of coarse particles is not injurious; if 1:2 the finely ground cement is slightly better, but its value is not much greater than that of cement containing 20 per cent of coarse particles.

In conjunction with the second series of tests a like series was made with Alsen's Portland cement. The results given in table IX of the appendix confirm the common opinion that the presence of coarse particles in any proportion is injurious in mortars of Portland cement and sand.

The writer, therefore, considers the test of fineness of cement of special importance with Portland cement, for which the requirement should be fixed as high as practicable, while for Louisville cement the requirement should depend on the amount of sand to be used in the mortar on the work. This remark is limited in its application to Louisville cement; the same may be the case with other natural cements, but should not be assumed in the absence of actual tests.

The hydraulic qualities of a cement are ascertained by immersing a mortar of neat cement in water for a longer or shorter time. The action termed blowing is the expansion of the mortar after setting, caused generally by the slacking and consequent expansion of free quick lime contained in the cement. This expansion tends to disintegrate the masonry in which the cement is used. Freshly manufactured Portland cement usually contains free lime, and in Europe it is usually required that the cement shall be exposed to the air in a layer only a few inches thick for a period of thirty days or so before being used. The best manufacturers attend to this before shipping. Cement shipped to this country is generally several weeks old before it can be used and there is less danger to be apprehended on this account.

It has been found that in some cases cement which has hardened

well under water and showed no indications of blowing after several days' immersion failed in the work; this has led to heating the water in which the samples are immersed or exposing the sample mortars to steam and hot air in order to hasten the test. Water in a partially filled covered vessel is heated and the pats of cement placed on a rack in the vessel above the surface of the water in the warm moist air, until set hard, then immersed in the water. The first, or among the first, to adopt this test was Mr. Faija, who heated the water to 110° or 115° F. and concluded the test in twenty-four hours. The mortars to be tested were mixed neat and spread with thin edges on small glass plates in the usual manner. If at the end of that period the pat still adhered to the glass, the cement was considered sound and safe; if it became detached or was cracked or friable at the edges or much curved the cement was considered unsafe in its present condition.

The test has been carried much farther by others and in some cases the temperature of the water has been raised to 180° F.

The writer has before him a letter from a well known firm of inspecting engineers, stating that they had tested a large number of natural cements of well known brands and every one of them had failed to pass the hot test when the temperature of the water was raised to 180°.

This result reduces the extreme hot test to an absurdity. Natural cements have now been used in this country for the greater part of a century and numerous works attest their value and reliability. For a large class of works they furnish mortars of sufficient strength and at much less cost than Portland cement and it would be a stupendous blunder to exclude them. At the same time it seems probable that the more moderate test adopted by Mr. Faija can be applied with advantage to all cements.

Less importance is now attached to the time of setting than formerly, although it is believed that a slow setting cement will show a greater progressive development of strength than one which sets quickly. Cements will become more slow setting by long storage. It is necessary sometimes to have a quick setting cement, as for instance when it is to be placed in running water; for work in the open air a cement somewhat slow to take its initial set is generally preferable, particularly for masonry, for which a batch of mortar may be mixed some time before being used, so that it may be put in the work before setting begins. A specification as to the time of setting, if employed at all, should be drawn with reference to the special requirements of the work.

In determining the strength of cement the tensile test of neat cement mortar has generally been used in England and the United States, the mortars being tested at the age of from one to seven days. In Germany both the tensile and compression tests are used, the latter preferred, the mortars being mixed in the proportions of one part of cement to three parts of sand by weight and tested at the age of twenty-eight days.

The object of testing cement is of course to determine its suit-

ability for the proposed work. In the great majority of cases the strain in the structure is compression; in a few cases, as in the footings of foundations, it is bending or shearing; in arches of floors, bending or a combination of bending and compression. The cases are rare where there is tension. The test of compressive strength would, therefore, be a better test of the merits of cement than any other in most cases. Its adoption in this country has doubtless been prevented by the great cost of the powerful machinery required for crushing the mortars.

Some of the earlier tests of cement were transverse and quite recently the adoption of this test instead of the tensile has been advocated. Mortars in actual work are more frequently subjected to bending than to tension; the apparatus for transverse testing is cheap and simple; the variation in uniformity of results from the same mixtures is not greater than in tensile tests and there is the considerable advantage of being able to check an unsatisfactory break by another test with one of the pieces of the same briquette, reducing the distance between supports. The tensile test has, however, done excellent service not only in determining the character of cement, but in raising the standards of manufacture; since the general adoption of practically uniform methods of making the test the results of different experimenters are comparable to a greater extent than formerly and a large amount of valuable information has been accumulated in regard to cement in terms of tensile strength. It is not likely to be replaced in this country by any other in the near future.

Assuming, then, that the strength of cement is to be tested by tension, what shall be the requirements of these tests, how shall they be carried out and what information will they give as to the character of the material?

If the real value of the cement for the work in hand is to be determined completely the cement should be tested with the same aggregates and with the same proportions as in the actual work and also for long periods of time; the neat cement test does not show the real value of mixtures with sand; the standard German test with one part of cement to three parts of sand by weight does not give the real value of other mixtures, and in this country the proportions of 1:2 are more common. A better indication is given of the character of a cement at twenty-eight days than at seven, but is still of less value than tests at the age of three months, six months or a year; how much less depends on the cement and on the peculiar requirements of the work; if the mortar in the work is required to bear its full load in twenty-eight days a test at that age would be satisfactory if it were certain that the mortar would not deteriorate later.

A good knowledge of the characteristics of a cement requires, therefore, a series of tests extending over a considerable time; the longer the time the less the chance of later deterioration and the more complete is the knowledge of the ultimate value of the article. It is needless to say that it is impracticable in ordinary cases to obtain any such knowledge of the cement after its purchase and before its consumption. Previous knowledge of the material is implied and is

essential. The terms of purchase must be conditioned on some short time test which will simply assure the purchaser that the lot of cement in question corresponds at any early period with other lots of the same brand, the character of which is known and satisfactory. Previous knowledge of the cement should be supplemented where practicable by series of tests made with different mixtures and at different ages. Two different classes of tests are, therefore, implied: First—The inspection tests, necessarily of short duration, to ascertain whether the cement during this period corresponds in behavior with cement of good quality from the same works; and, second, long time tests with varying mixtures of cement and sand to establish its specific value for the work in hand and also to detect any changes in manufacture which affect the product injuriously or otherwise.

The writer's practice as regards tests of strength has been for several years as follows:

First—A neat cement tensile test at the age of seven days. Samples of cement are taken from ten barrels in each one hundred; each sample is tested for fineness, expansion and strength in the manner specified in the rules recommended by the Committee of the American Society of Civil Engineers, excepting that ice water is used in mixing to retard the initial setting so that the briquettes may be finished before setting begins and excepting also that the mortars are mixed with a hoe in a box specially made for the purpose whereby the work is done more quickly and thoroughly.

The writer does not mix the several samples of cement together as sometimes recommended because he considers it important to determine the variations in the material and, therefore, tests separately the cement from each barrel sampled.

Second—From each shipment of a thousand barrels or thereabout a considerable quantity of cement is taken from each of ten or more barrels and mixed together thoroughly. Ten briquettes are then made of neat cement for breaking by tension at the end of each of the following periods: seven days, twenty-eight days, three months, six months and one year; another series is made with equal parts by volume of cement and sand; and a third series with one volume of cement to two volumes of sand, which are the proportions ordinarily used on the work. These series made at frequent intervals have been found of much interest and value as a check on the general run of the cement.

In this system of tests the seven-day test is relied upon to show any marked variation from the usual output of the manufacturer. It does not determine the relative value of different cements or the ultimate strength of the cement tested; the proper requirement at seven days varies with different brands and at different seasons. Some of the cement mills are closed on the approach of cold weather and sales are made from stock on hand. Mortars made from natural cements which have been stored some time will show much less strength at seven days than if made from cement freshly ground, while they may become ultimately quite as strong.

The tests in series are relied upon to show the actual value of the

cement and will detect in a few months any deterioration in the output. By the combination of short and long time tests with the usual tests for fineness and blowing it is believed that there is little danger of accepting poor cement.

The sand used in these tests is ordinarily the same used on the work, except that it is sifted and only the portion taken that passes through a No. 20 sieve and is retained on a No. 30. The unit of volume is a Louisville cement barrel, which is found to measure 3.75 c. f. between the heads. This barrel will contain 397 lbs. of dry Mississippi River sand of standard size well shaken down.

The volume of a barrel of Louisville or other natural cement is taken at its packed volume in the barrel, 3.75 c. f.

The volume of a barrel of Portland cement is taken the same for convenience, although the actual volume of the barrel is a little less.

The net weight of a barrel of natural cement is 265 lbs.; of a barrel of Portland cement about 375 lbs. A comparison of these weights with the weight of a barrel of sand gives the data for weighing out the proper amounts of materials for each briquette, which are thus determined directly by weight. The writer considers it important that each experimenter in reporting results should give the proportions by weight as well as by volume, on account of the great diversity of opinion that exists as to the volume of a barrel of cement.

The water for each briquette is measured in a drug graduate and is the amount which with vigorous mixing will make a stiff mortar. The mortar is packed into moulds with the hands and smoothed off with a trowel.

The briquettes are kept in the air under a thick, damp cloth twenty-four hours after mixing, then immersed in water of a temperature of 60° to 70° F. until they are to be broken, when they are removed from the water and broken immediately. They are of the usual standard form, 1″ square at the smallest section.

The amount of water used in the mortar affects their strength considerably, especially at early periods. Several years ago, while in local charge of the improvement of the St. Marys Falls Canal, under the immediate direction of the late General Godfrey Weitzel, the writer made a series of tests, more than 5,000 in number, with Portland and natural cements for the purpose of comparing the strength of mortars of different degrees of plasticity. Although made more than fifteen years ago, the work was done carefully, practically in accordance with present rules for testing, and the tests are still of value. The results are given in condensed form in tables X and XI of the Appendix.

The results are more significent if arranged to show ratios of strength, and this is done in tables XII and XIII, the mortar containing the least amount of water being made the basis of comparison. Both Portland and natural cement mortars of neat cement show little difference in ultimate strength after six months, whether mixed dry or as grout, but at shorter periods the difference is more marked, particularly with the natural cements. With mortars containing sand the final difference is somewhat greater, but still not very important.

With both cements it is clear that the use of the smallest amount of water leads to an earlier development of strength, and short time tests will give much higher results with dry mixtures. For test room purposes this is of no importance in itself, unless greater uniformity can be obtained in different tests of the same mixture, but other things being equal, that degree of plasticity may be considered best which conforms most closely with the mortar used on the work. It is of more importance that some certain degree of plasticity should be established as standard to facilitate a comparison of results obtained by different persons.

But although the precise amount of water used in testing appears to be of no great moment, provided exact uniformity is maintained, the case is different in actual work where the aim should be to obtain the degree of plasticity best suited to the work in hand. About twenty-five years ago the manufacture of the material known as Coignet-béton was introduced into the United States from France. It was a mortar or concrete, without stone, and its excellence depended, after the careful selection of materials, upon, first, thorough and prolonged mixing; in order to permit this a very slow setting cement was required; the amount of water was carefully regulated so as to give a rather dry yet somewhat viscous paste; second, thorough ramming with heavy iron rammers in layers not exceeding $1\frac{1}{2}''$ to $2''$ after ramming. The required amount of water was the greatest that could be used without causing the layer to quake on being rammed. The result of this method was the production of a dense, uniform material which hardened quickly and gave excellent results, but at great cost as compared with common concrete of cement mortar and crushed rock.

It is perhaps largely on account of the excellence of Coignet-béton that it has become almost the universal custom in this country to specify a mortar of the same degree of plasticity for ordinary concrete and require that the concrete shall not quake when rammed. This overlooks or neglects several important differences between the two materials. Before pointing out these, however, it may be well to go back a step and inquire whether the assumed superiority of Coignet-béton is not rather an earlier development than an ultimately greater strength. In this connection attention is again called to tables XII and XIII.

The briquettes reported in these tables were $1\frac{1}{2}''$ square at the smallest section, which was the usual size at that time. The large moulds rendered it practicable to tamp the mortar, and those made with the least amount of water were so dry that perfect specimens could only be produced by vigorous tamping with a stick shod with metal, the mortar being added in small portions, enough for a layer $\frac{1}{4}''$ to $\frac{3}{8}''$ thick at a time. The mortars were mixed in a small box with a hoe, only enough for one briquette at a time, and the mixing required the utmost effort of a man of unusual activity and strength. With mortars thus mixed and tamped it is believed the briquettes resembled Coignet-béton very closely. The weight of the briquette

with least water was about 3 per cent greater than the one of medium plasticity and 6 per cent greater than the one of grout.

The tables show clearly that the superiority of the briquette resembling Coignet-béton at early periods is marked; but that after six months it practically disappears. There seems no reason to doubt that the same result would be found in actual work where, indeed, the relative conditions, if different, would be less favorable to the Coignet-béton.

But passing this point and assuming for a moment that Coignet-béton is permanently stronger than ordinary mortar of like composition, it must be pointed out that the dry mortar ordinarily found on the concrete mixing platform is a very different material. Instead of the complete and prolonged grinding required to produce the former whereby all the particles of sand are covered with cement paste, the mixing, whether done in the concrete mixer or by hand, is comparatively limited and the sand is much less perfectly coated with cement paste than in Coignet-béton or than it would be if more water were added. Besides the difference in the quality of the mortar the ramming of concrete containing stone is much less effective in compacting the mortar than if the stone were absent. The force of the blow is largely consumed in jamming the stones together instead of compressing mortar; for the best effect the layers of concrete must be 6″ to 10″ in thickness before ramming, instead of 3″ or 4″ as with Coignet-béton, which again renders the ramming less effective in compressing mortar, and it may, indeed, be doubted if prolonged ramming on the surface of a dry mixture of ordinary concrete has much effect in compacting the mortar at the bottom of the layer; the result is the formation of a mass composed of alternate layers of dense and porous material, the whole being deficient in strength.

In dumping concrete from a bucket it often happens that some of the fragments of stone become separated from the mortar, particularly if the mortar is dry. The competent inspector will not permit mortar to be thrown on visible groups of these stones, where no amount of ramming will force dry mortar through, but will have them thrown on the mass and separated and worked into it with the shovel; still, there is no doubt that similar groups of loose stones are covered up and remain unseen; unless the concrete becomes a quaking mass in ramming, the interstices of the stones will not become filled with mortar and voids will exist in the mass. Even greatest strength is not always of first importance; in many cases it is of far more importance that a mass of concrete should be solid and fill all spaces than that it should have the highest degree of strength, as, for instance, in the crib work of pier foundations or where narrow spaces are to be filled between timbers. Even with plastic concrete it requires constant vigilance to secure tolerable work in such cases, while with the dry mixtures ordinarily specified it is impossible.

Concrete has been used in harbor and canal works in England in large quantities and the experience of English engineers with this material has been far greater than our own; several failures of Portland cement have occurred and have occasioned a careful study of the

methods best adapted to secure under practical conditions a dense and impermeable concrete.

The failures referred to have occurred where the proportion of cement was too small or the manipulation so imperfect that the concrete was somewhat porous. In places where such porous concrete was exposed on one side to a varying head of sea water, tending to force the water into the pores of the concrete, the lime of the cement was, to some extent, replaced by magnesia from the sea water, forming a hydrate of great expansive force, which disrupted the mass. The remedies proposed and found adequate consisted in making the concrete impermeable by increasing the proportions of cement and by improving the manipulation of the concrete so as to secure the greatest density. This is precisely the end sought by those specifying dry mixtures; a few quotations will be made showing that the best English practice is opposed to the method.

In a paper describing the Biloela Graving Dock, N. S. W.,[1] the resident engineer, Mr. E. W. Young, says "the concrete in the altars, backing, etc., was at first put in rather dry and punned; but subsequently it was deposited in thinner layers with a greater quantity of water and trampled down. A more water-tight concrete was thus obtained." In the discussion of the paper Mr. Reid Bell, engineer of the Clyde Navigation Graving Dock No. 1, "agreed with the practice of dispensing with punning in concrete work, having found more satisfactory results from laying the concrete in 9" or 12" layers and simply working it with the edge of a shovel, sufficient water being used in mixing to allow the mortar to set well around the larger aggregate. In fact, the mortar in concrete should be quite as wet as that used for setting masonry." Mr. John Kyle, who had superintended the construction of concrete work at Colombo Harbor, containing 200,000 cu. yds., and works on the Manchester Canal, containing 500,000 cu. yds., advocated a stiffer mortar, saying: "Water should never be added after a thick, firm, pasty condition had been obtained in the banker." This, however, appears to be wetter than often specified here.

Mr. Henry K. Bamber, in a paper on "Portland Cement; Its Manufacture, Use and Testing,"[2] describes a test of three sets of blocks, made in duplicate, of Portland cement concrete containing one part of cement to two parts of sand and four parts of shingle, exactly alike in all respects except as to the amount of water used; the first set contained a full amount of water; the second three-fourths as much; the third one-half as much as the first. One of each set was placed on a sea wall for twelve months where covered and uncovered by each tide. At the end of that time they were brought on land and carefully broken through the middle. The results were as follows: "No. 1, with the full quantity of water, was very hard and perfectly sound, and quite dry through to the surface. No. 2, with three-quarters of the full quantity of water, was dry in the middle,

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[1] Proc. I. C. E., Vol. CXI.

[2] Proc. I. C. E., Vol. CVII.

but on every side the water had penetrated about three inches and had much weakened the block. No. 3, with half the full quantity of water, was wet quite through and was easily broken up, the water having been able to percolate continually through the block and having dissolved much of the lime." The fellow block of each pair was placed in fresh water for the same time with the same results as to penetration and strength of blocks.

As to the relative compactness of wet and dry concrete, the same author describes preparing two batches of concrete of the same proportions and amounts, except as to water, one containing enough water to make a very wet mortar, the other only one-half as much. The wet batch exactly filled a box of 18″ cube; only seven-eighths of the dry batch could be packed into it.

Mr. Bamber adds:

"Frequently, with the object of making concrete extra strong, it is mixed comparatively dry; and then astonishment is felt when the work fails. A full quantity of water is an absolute necessity, but on the other hand, the concrete must not be drowned in water, which would separate the particles, washing away some, and preventing setting altogether."

In a discussion of Mr. Bamber's paper, Mr. Harrison Hayter, then Vice President, now past President of the Institution, remarked: "With regard to the quantity of water that should be used in Portland cement mixtures, the common practice has been, as seen continually in specifications, to use as little water as possible; but Mr. Bamber rightly urged the use of as much as the mixture would readily take up, otherwise the constituent parts could not be thoroughly incorporated and chemically combined." Mr. E. Leader Williams, chief engineer of the Manchester Canal, "was satisfied much concrete was used in too dry a state."

Mr. A. R. Binnie, in the same discussion, said: "When attempting to make solid impervious concrete, they must of necessity have water in superabundance until the mass was made almost gelatinous; and then they get a perfect mixture."

Several other prominent members expressed concurring views, but space will only be taken here to quote Mr. James Mansergh, who, members of the Society will remember, has recently been engaged as consulting engineer by the city of Toronto. Mr. Mansergh said that in "his work concrete had usually to be made water tight and for many years he had insisted upon much more water than was sometimes approved of, as it was otherwise hopeless to make concrete like a close, compact, impervious conglomerate as obtained with 5 of clean hard grit stone and sand to 1 of cement. More first-class material was made into bad concrete for want of water than of cement."

In a paper on "Portland Cement Concrete and Some of Its Applications,"[3] Mr. E. A. Burmays described some great works at the Royal Dockyard at Chatham, executed under his direction and took

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[3] Proc. I. C. E., Vol. LXII.

strong ground in favor of using an abundance of water in concrete, so much indeed that the rammer was dispensed with and the concrete was spread and worked with the shovel and by treading. This was dissented from in some degree by Mr. C. Colson, who said: "No doubt some advantage was gained in the increased facility with which wet concrete was manipulated as compared with dry; but, on the other hand, there was great risk, indeed, a certainty of some of the cement being carried off by an excess of water, and this acting detrimentally on the mass in a two-fold manner, at the same time an error could be made in having too little water. It was necessary that there should be sufficient water to act in some measure as a vehicle, by which the matrix was carried into the interstices of the mass."

It thus appears that while there is considerable diversity of opinion as to the exact degree of wetness concrete should have, none of the engineers quoted advised such dry mixtures as are commonly required here. The writer believes that a more homogeneous, a denser, and stronger material will be obtained if the concrete is made so wet that the mass will quake after ramming; and, furthermore, that where concrete is to be placed in contracted spaces, as between timbers, it may be with advantage made still wetter, so that it can be pushed into place with the shovel and by treading, filling all the spaces solidly, with no important diminution of strength at any point, but stronger as a whole.

TABLE VII.

EFFECT OF FINE GRINDING ON LOUISVILLE CEMENT.

Each result the mean of 5 tests at 6 months. Cement sifted through No. 80 sieve.

Mortar without sand.	Sifted cement, 30 oz. Screenings, 0 "	Sifted cement, 27 oz. Screenings, 3 "	Sifted cement, 24 oz. Screenings, 6 "	Sifted cement, 21 oz. Screenings, 9 "	Sifted cement, 18 oz. Screenings, 12 "	Sifted cement, 15 oz. Screenings, 15 "	Sifted cement, 12 oz. Screenings, 18 "	Sifted cement, 9 oz. Screenings, 21 "
Tensile str. per □" in lbs.	359	377	377	359	326	327	320	313

Mortars of Cement 1; Sand 1, by measure..	Sifted cement, 20 oz. Screenings, 0 " Sand, 26 "	Sifted cement, 18 oz. Screenings, 2 " Sand, 26 "	Sifted cement, 16 oz. Screenings, 4 " Sand, 26 "	Sifted cement, 14 oz. Screenings, 6 " Sand, 26 "	Sifted cement, 12 oz. Screenings, 8 " Sand, 26 "	Sifted cement, 10 oz. Screenings, 10 " Sand, 26 "
Tensile strength per square inch in lbs.	381	392	371	349	312	304

TABLE VIII.

Tests of Louisville cement to determine effects of fine grinding.

The cement was first passed through a No. 100 sieve. In the following table the material which passed through this sieve is called sifted cement; the material retained on the sieve is called screenings. Sand was ordinary river sand of fineness 30-40.

Proportions by weight. All tests at 6 mos.

Sifted cement	10	9	8	7	6	
Screenings	0	1	2	3	4	
Sand	0	0	0	0	0	
Tensile strength, lbs., per square inch	363.4	376.4	376 2	347.2	389.4	
	273.7	279.3	281.5	261.5	306.9	
	321.6	349.5	295.4	304.8	261.4	
Means	319.6	335.1	317.7	304 5	319.2	
Sifted cement	10	9	8	7	6	
Screenings	0	1	2	3	4	
Sand	20	20	20	20	20	
Tensile strength, lbs., per square inch	299.4	310.0	284.8	264.2	216.0	Proportions about 1 cem. to 1⅓ sand by volume.
	226 6	226.1	224.6	229.8	229.2	
	322.4	357.8	359.2	345 6	302 5	
Means	282.8	298.0	289.5	279 9	249.2	
Sifted cement	10	9	8	7	6	
Screenings	0	1	2	2	4	
Sand	40	40	40	40	40	
Tensile strength, lbs., per square inch	210.8	188.0	196.6	187.5	176 3	Proportion about 1 cem. to 2⅔ sand by volume.
	149.5	153.0	142.5	126.0	113 0	
	202.5	197.3	173.6	181.0	176.4	
	232.3	227.4	209.4	198.6	179.1	
Means	198.8	191 4	180.5	173 3	161.2	

Each result is the mean of ten tests.

TABLE IX.

Tests of Alsen's Portland cement to determine effects of fine grinding. The cement was first passed through a No. 100 sieve. In the following table the material which passed through this sieve is called sifted cement: the material retained on the sieve is called screenings. Sand was ordinary river sand of fineness 30-40.

Proportions by weight. All tests at 6 mos.

Sifted cement..	10	9	8	7	6	
Screenings	0	1	2	3	4	
Sand	0	0	0	0	0	
Tensile strength, lbs., per square inch.....	596 7 643.1	615.0 627 6	628.7 688.6	668.3 716.2	705.2 718.4	
Means....	619.9	621.3	658.6	692.2	711.8	
Sifted cement..... ..	10	9	8	7	6	
Screenings....	0	1	2	3	4	
Sand	13	13	13	13	13	
Tensile strength, lbs., per square inch . ..	461.9 493.2	415.0 503.0	402.0 469.6	355.1 427.0	343.3 361.3	Proportions about 1 cem. to 1⅓ sand by volume.
Means................	477.6	459 0	435.8	391.0	352.3	
Sifted cement.......	10	9	8	7	6	
Screenings.... .. .	0	1	2	3	4	
Sand	26	26	26	26	26	
Tensile strength, lbs., per square inch......	337.6 306.3	311.0 286 4	264.0 261.0	260.0 237.0	241.4 206.8	Proportions about 1 cem. to 2⅔ sand by volume.
Means........	322.0	298.7	262.5	248 5	224.1	

Each result is the mean of ten tests.

TABLE X.

TENSILE STRENGTH OF PORTLAND CEMENT MORTARS OF DIFFERENT DEGREES OF PLASTICITY.

Each result in the following table is the average of 125 tests, 25 from each of the following named brands: K. B. & S., White Bros., Saylor's, Phinney's and Eagle's.

Description of Mortar.	Proportion by Measure.		Strength in lbs. per square inch.					
	Cem't.	Sand.	7 Days.	30 Days.	90 Days.	6 Mos.	9 Mos.	1 Year.
Mixed with as little water as would make perfect briquettes when tamped in moulds..........	1	0	410	570	695	725	725	750
Moderately stiff mortar......	1	0	390	540	710	717	734	738
Thin mortar or grout........	1	0	350	500	686	712	685	734
Mixed with as little water as would make perfect specimens when tamped in moulds.....	1	1	212	300	392	423	443	452
Moderately stiff mortar......	1	1	190	292	368	411	438	438
Thin mortar or grout.......	1	1	180	270	362	385	426	430

TABLE XI.

TENSILE STRENGTH OF NATURAL CEMENT MORTARS OF DIFFERENT DEGREES OF PLASTICITY.

Each result in the following table is the average of 50 tests, 25 from each of the following named brands: Louisville, Milwaukee.

Description of Mortar.	Proportions by Measure.		Pounds per Square Inch.					
	Cement.	Sand.	7 days	30 days	90 days	6 mos.	9 mos.	1 year
Mixed with as little water as would make perfect briquettes when tamped in the moulds...	1	0	148	250	359	372	340	308
Moderately stiff mortar..........	1	0	116	220	335	371	334	300
Thin mortar or grout............	1	0	100	172	311	363	358	300
Mixed with as little water as would make perfect briquettes when tamped in the moulds...	1	1	52	120	238	298	285	299
Moderately stiff mortar..........	1	1	38	92	212	283	253	268
Thin mortar or grout	1	1	28	75	182	255	227	246

TABLE XII.

COMPARISON BY RATIOS OF RESULTS GIVEN IN TABLE X.

Portland Cement.

Description of Mortars.	Proportions by Weight.		Ratios of Strength.					
	Cement.	Sand.	7 days	30 days	90 days	6 mos.	9 mos.	1 year
Mixed with as little water as would make perfect briquettes when tamped into moulds ...	1	0	100	100	100	100	100	100
Moderately stiff mortar	1	0	95	95	102	99	101	98
Thin mortar or grout...........	1	0	85	85	99	98	94	98
Mixed with as little water as would make perfect briquettes when tamped into moulds....	1	1	100	100	100	100	100	100
Moderately stiff mortar..........	1	1	90	97	94	97	99	97
Thin mortar or grout...........	1	1	85	90	92	91	96	95

TABLE XIII.

COMPARISON OF RESULTS GIVEN IN TABLE XI. NATURAL CEMENTS.

Description of Mortar.	Proportions by weight.		Ratios of Strength.					
	Cem't.	Sand.	7 Days.	30 Days.	90 Days.	6 Mos.	9 Mos.	1 Year.
Mixed with as little water as would make perfect briquettes when tamped into moulds.....	1	0	100	100	100	100	100	100
Moderately stiff mortar.. ...	1	0	79	88	93	100	98	97
Thin mortar or grout........	1	0	68	69	87	98	105	97
Mixed with as little water as would make perfect briquettes when tamped into moulds......	1	1	100	100	100	100	100	100
Moderately stiff mortar.....	1	1	73	78	89	95	89	90
Thin mortar or grout........	1	1	54	63	77	86	80	82

ULTIMATE STRENGTH OF SLOW vs. RAPID SETTING CEMENT.

By Ellis B. Noyes, M. A. S. C. E.

Referring to the question as to what extent the testing of cements is useful in connection with various classes of work, I would say that, in my opinion, unless the tests can be made by an expert of wide experience who has made tests with a variety of cements and covering considerable periods of time, they are of very little value. The effects of varying proportions of water, temperature of water of mixture and for immersion, methods of handling, effects of sand, etc., vary more or less with each variety of cement. These variations are especially noticeable with American natural cements, to which the following remarks will be confined.

The standard specifications for cement tests are based to a large extent on the behavior of certain Eastern cements and are usually limited to the one and seven day tensile test neat, test for time of setting and for cracking. The tensile test required at one and seven days has been forced up without much regard to its effect on longer time tests, often reducing such longer time tests materially. I have in mind an American natural cement on which I once made thousands of tests, and rejected thousands of barrels because one, seven and twenty-eight day tensile tests were not up to requirements. The following are samples of tests continued to the end of the year, the mixture being 1 cement to 1 sand by weight:

7 days.	28 days	6 months.	1 year.
19	41	210	518
12	24	136	530
42	115	202	334
71	182	283	260

I could cite other cements of which the same would be true.

I do not wish to be understood by this as advocating the requirement of lower tests for cements. There are natural cements in which the raising of the early tests raises all later tests, and in such cases a high requirement is desirable. I wish specially to emphasize the fact that testing may be injurious as well as beneficial unless long experience and judgment are combined in the testing.

As a usual thing, a tensile test of a sand mixture, a test for cracking and a test for time of setting is all that will be necessary or desirable.

As to the effect of water on mixtures it is broadly as follows:

Beginning with a mixture of the consistency of damp loam, successive increases in the amount of water will decrease the early strength and increase the later strength to a point to be determined for each cement, after which further additions of water decrease the strength throughout.

The general effect of cold is to lengthen the time necessary to acquire a given strength.

QUAKING CONCRETE.

By Ernest L. Cooley, M. W. S. E.

For hydraulic work, where concrete must be water tight, there ought to be at least a small excess of cement in the mortar and of mortar between the broken stones to insure the filling of all the voids. When the voids are full of mortar properly made, without an excess of water, the grains of sand and the broken stones are not in hard contact and the concrete will quake when tamped without getting sloppy.

Take a sample of mortar mixed stiff, as used for setting stones in masonry, and work spalls or broken stones into it with a trowel and then the mass will quake. The repeated jar of a hammer on a small stone set in stiff mortar will make the mortar thin and quaky. Such stiff mortar is not usually considered too wet. Properly made, quaking concrete will not contain a larger percentage of water in its mortar than the above stiff mortar, and probably not so much. The opponent of quaking concrete does not object to using mortar in stone masonry, which may and probably does contain more water than the mortar in the quaking concrete. When concrete is made stiff with cement and mortar enough to fill all the voids and is laid in thin layers not over 4 or 5 inches thick which quake after sufficient tamping, it is reasonable to suppose that the voids are practically filled and that it is time to stop tamping.

By experiment, a certain measure of dry sand well shaken and struck settled nearly 1-10 its volume, when about 35 per cent. of its volume of water was poured into it without jar. Afterwards, when jarred, it settled still farther and free water appeared on its surface. Damp sand behaved in a similar manner. It may be inferred from this experiment that the presence of sufficient water in making concrete will enable it to adjust its parts so as to occupy a smaller space than would be filled by dryer concrete under conditions which obtain in practice. It is not the intention to deny experiments made by an artist in a laboratory under conditions which do not obtain in field practice with common labor.

When lean concrete is made, in which the mortar will not fill all of the voids, the broken stones may and probably do remain in hard contact. In such a case the mixture should be rather dry and tamped hard without quaking. It would be bad practice to make such a lean mixture wet enough to quake when tamped. In either case, with a lean mixture the concrete must unavoidably be honeycombed or porous and may contain lean streaks. However, such lean concrete may pass for some purposes.

DISCUSSION.

By Prof. Ira O. Baker, M. W. S. E.

5. *The influence of the amount of water used in forming paste and mortar.*

Fig. 41 shows the effect of water upon the tensile strength of neat Portland cement mortar of various ages. Fig. 42 the same for neat

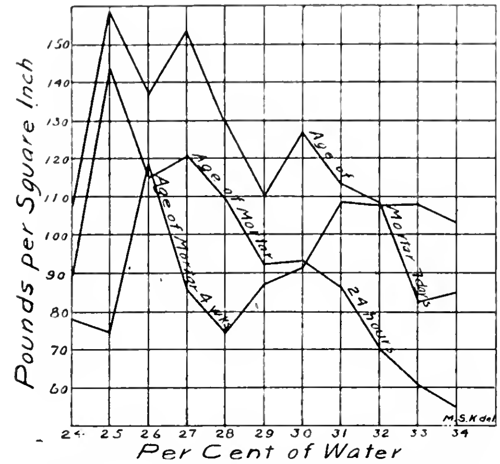

Fig. 41. Effect of water on tensile strength of neat Portland cement mortar.

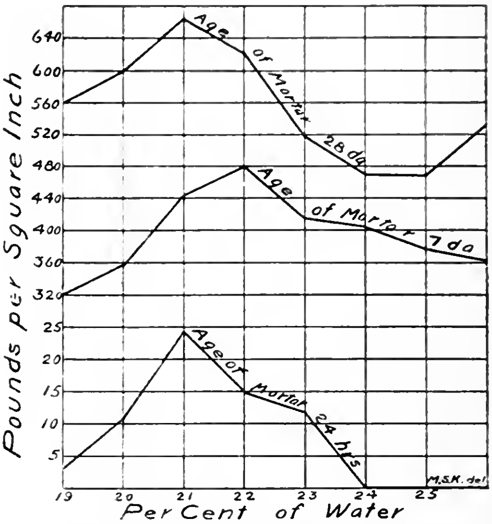

Fig. 42. Effect of water on tensile strength of neat Louisville cement mortar.

Louisville cement. The lower line in Fig. 42 represents a different brand than that of the two upper lines. Each point in these diagrams represents the mean of five briquettes all made by the same person under the same conditions. The cement was bought upon the market and was stale when used. The particular brand is not now known.

Fig. 43 shows the effect of water upon the tensile strength of neat Hilton's (English) Portland cement mortar 7 days old. The two upper lines and the lowest line represent different experiments by the same men. Each point is the mean of four or five briquettes. Fig. 44 shows similar data for neat Black Diamond Louisville cement mortar.

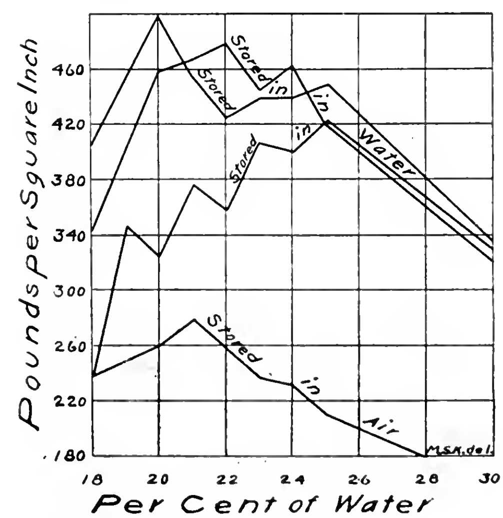

Fig. 43. Effect of water on tensile strength of neat Hilton's Portland cement mortar at 7 days.

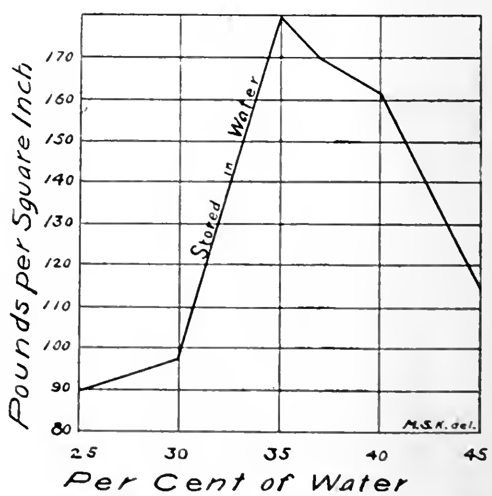

Fig. 44. Effect of water on tensile strength of neat "Black Diamond" Louisville cement mortar at 7 days.

The above experiments, as well as those presented elsewhere in

this discussion, were made by the writer's students in the Cement Laboratory of the University of Illinois, and the diagrams were drawn by the writer's assistant, Mr. M. S. Ketchum, B. S.

9. How cement mortars are affected by different qualities of sand.

The following table shows the effect of the fineness of the sand upon the tensile strength of neat cement mortar seven days old. The results are the means of five briquettes by each of seven experiments:

Kind of Sand.	Tensile Strength in lbs. Per Square Inch.
Crushed quartz, imported, German standard, passed a No. 20 sieve and caught on a No. 30	81.5 ± 5.2
River Sand, " " 20 " " " " " 30	90.3 ± 3.0
" " " " 30 " " " " " 50	77.1 ± 5.7
" " " " 50 " " " " " 75	54.6 ± 3.2
" " " " 75 " " " " " 100	39.3 ± 2.9
" " " " 100 "	35.7 ± 2.9

10. To what extent can cement mortar plaster be relied upon to adhere to cement mortar in concretes, especially when Portland cement is used for plaster and natural cement for concrete.

The only data on this subject in the records of the Cement Laboratory of the University of Illinois are: At seven days the adhesion of neat Saylor's American Portland cement mortar to briquettes of Portland cement at least a week older was 37 per cent of the cohesive strength of the neat cement at the same age, and of Utica cement (Rosendale type) to Portland briquettes was 24 per cent of the cohesive strength at seven days.

General. An important matter in determining the tensile strength of cement mortar is the method of filling the briquette molds. This is ordinarily done by hand, in which case there are two sources of considerable error, viz.: (1) The difficulty of an observer's filling the molds uniformly; (2) the variation of standard between different observers. After considerable practice an intelligent experimenter may become an expert, and secure reasonably uniform results; but usually observers equally expert will differ considerably in the results obtained. To obviate this difficulty at least two machines for filling molds have been invented and are upon the market. The first is known as the Boehme hammer apparatus,* and is used in the German official governmental testing laboratories; the second was invented by S. Bent Russel for use in connection with the extension of the water works system of St. Louis, Mo.† The accompanying table shows the relative results obtained by the different methods of molding. Each result is the mean of six briquettes. The probable errors of the several results show the accuracy of results by different observers, and the probable errors of the means show the relative accuracy of the several methods of molding.

* For an illustrated description see Engineering News, Vol. 17, P. 260.
† For an illustrated description see Trans. Am. Soc. C. E., Vol. 27, P. 441.

Notice that the Russel machine gives results only 50 per cent of those by the Boehme apparatus, while hand molding gives 65 per cent. Obviously, then, the method to be employed in testing cement is a matter of considerable importance. At first glance it might be concluded that because the probable errors for hand molding and for the hammer apparatus were the same, that these methods gave equally uniform results; but notice that the probable error for hand molding is 9 per cent, while that for the hammer apparatus is only 6 per cent; the probable error for the Russel machine is also 6 per cent, and hence it and the hammer apparatus give equally uniform results.

TABLE XIV.

EFFECT OF DIFFERENT METHODS OF MOULDING 1 TO 3 CEMENT MORTARS.

Ref. No.	Observer's Initials.	Brand of Portland Cement.	Tensile Strength in lbs. per square inch at 7 days. Briquette molds filled.		
			By Pressure of Thumb.	With Boehme Hammer Apparatus.	With Russel Lever Machine.
1	H. & K.	Star Stettin.	216 ± 20	271 ± 24	150 ± 14
2	T. & V-O.	Dycherhoff's.	105 ± 7	238 ± 8	146 ± 5
3	B. & E.	Saylors.	71 ± 1	170 ± 7	52 ± 1
4	B. & M.	Heyn's.	164 ± 4	233 ± 4	108 ± 5
5	B. & C.	"	152 ± 13	228 ± 16	116 ± 7
6	L. & O.	"	188 ± 20	235 ± 5	100 ± 2
		Mean.	149 ± 13	229 ± 13	112 ± 7

The following table shows the variation in results by different methods of hand molding. Every precaution was taken to have every condition the same, except the methods of molding:

TENSILE STRENGTH, IN POUNDS PER SQUARE INCH, OF NEAT SAYLOR'S PORTLAND CEMENT MORTAR AT SEVEN DAYS.

1. Molds filled and smoothed down with trowel without ramming. 459 ± 24
2. Molds completely filled and then pressed into place with thumb 471 ± 25
3. Molds partially filled and pressed into place with thumbs after adding each increment of mortar .... 475 ± 18
4. Molds completely filled and tamped with oak rammer ¾ x ¾ x 12 inches........ 517 ± 17
5. Molds completely filled and tamped with iron rammer ⅜ inch round, 1-foot long .... 493 ± 16
6. Same as 4th except that rammer was pounded with a 10-ounce hammer........ 480 ± 22

Notice that the smallest result, the first, is 88 per cent of the largest, the fourth. The above results are by a single observer, and are probably more uniform than could be reasonably expected under similar conditions.

I recently visited in a single day the laboratories of three cement experts, each of whom tests large quantities of cement. The difference in the method of molding was very marked. The first filled the mold about one-fourth full and tamped it "slowly and thoroughly four times around" with a brass rammer weighing one pound and having a circular face seven-eighths of an inch in diameter, and

repeated the process for each succeeding quarter. The second filled the mold "about one-third full" and tamped it with a steel rammer weighing about a pound and having a face three-eighths of an inch square. The third filled the molds and pressed the mortar into place with his thumbs. Naturally these three observers may obtain quite different results from the same cement, even though their methods were alike in all particulars except the method of filling the molds, which probably they are not. Apparently the method of filling the molds is the source of greatest error in testing cement, and a standard method of procedure is very desirable.

SILICIA-PORTLAND CEMENT.

By Charles Sooysmith, M. W. S. E.

In response to the circular inviting matter concerning cements, it occurs to me that my experience with a product of Portland cement and sand ground together may be of interest. In the construction of the foundations of the great Cathedral of St. John the Divine which has been started near the northwest corner of Central Park in this city, there has been used in the neighborhood of 10,000 barrels of a mixture of one part of Portland cement with one part of sand, these being ground together in a ball mill so that the sand was as fine as the cement was originally, and the cement itself very much finer. This mixture was used with twice its weight of sand, the same as pure cement would be used, with two parts of sand, thus making a mortar consisting of one-half part of cement, one-half part of ground sand and two parts of coarse sand; in other words, one part of cement to five parts of sand. By actual test, both in the laboratory in the usual ways and on large cubes by compression, this product, one-sixth of which was cement, averaged a trifle stronger than specimens made with the same cement and sand not ground together, in the proportions of one of cement to two of sand. Tests of other proportions of grinding show that by grinding one-fourth part cement with three-fourth parts sand and then mixing this with two parts unground sand, the product in twenty-eight days stands more than one part of the same cement mixed with three parts of unground sand; in other words, the mixture containing one part in twelve, where grinding was resorted to, is stronger than the mixture containing one part in four without the grinding.

The advantages shown by these tests are also shown by other proportions; in fact, it is possible to make a very fair mortar with less than one-twentieth part of cement. By using the ground mixture the mortar contains a much smaller proportion of voids; in other words, it is more compact and impervious to water. Hence it should stand exposure to frost much better than ordinary coarse sand mortar, and it works much better on the trowel than the usual mixture of cement and sand, being more of the consistency of lime mortar.

The reasons for this strength are quite obvious, the particles of ground sand going to fill spaces that would otherwise be voids, or

which would have to be filled with cement; and each particle of cement being broken into many particles, thus making the cement reach further as a binder between the particles of sand; in other words, more effective as a coating and cementing material. There may be some additional reasons, but the two mentioned are doubtless the most potent. The sand cement for the Cathedral was ground in a mill in Brooklyn, the sand being kiln-dried.

The idea of using cement in this particular way has been developed by F. L. Smidth, of Copenhagen, who has taken out patents covering the process of grinding the two materials together and then using the resulting product as a cement. Companies have been formed in most of the large countries of the world, and the product is coming into extensive use in Europe, and seems likely to be largely used here, where arrangements have been perfected for the erection of plants in various parts of the country, that in Brooklyn being now in full operation. The product has been in use in works and public buildings in Copenhagen for two or three years, and there are tests covering a great variety of mixtures, running over two or three years, so that the facts shown by the short tests above referred to for the Cathedral are fully confirmed by the results of the long time tests from Europe.

I beg to say in connection with this matter that I am interested in a business way in the product, and am fully aware that it would be improper to use the Society in any way for advertising purposes, but it has seemed to me entirely proper to mention the matter in connection with the Cathedral work, and as one of great engineering interest, and I trust the communication will be taken in the spirit in which it is meant.

DISCUSSION.

By J. W. Dickinson.

It was with the greatest satisfaction that I received the notice that your Society intended to investigate the broad subject of cements and cement testing. Portland cement is certainly an important material in modern construction, and a marked advance has been made in its manufacture during the past five years. It might be difficult to say whether the largely increased use has brought forth a better cement, by turning capital and brains in that direction, or whether the improved methods of manufacture, and the adapting of practical requirements to the industry, particularly by the American manufacturer, has made the use of Portland cement feasible, and even desirable, in many directions, and uses that were impossible when this country was confined to the poor cement supplied by the English and Continental manufacturer a decade ago.

We trust that a conclusion will be reached by your body, regarding specifications and methods of testing, so that something like an authoritative utterance will result.

With due respect to all, it must be admitted that comparatively little is known of cements by the majority of engineers and archi-

tects, and without such knowledge it is, of course, impossible for intelligent specifications to be drawn.

For the past eight or ten years this country has received annually from Europe hundreds of thousands of barrels of so-called Portland cement that are not equal to our own common cements, and yet we are all familiar with specifications calling for "imported cement," special reliance being placed on the word "imported." Such specifications are about as specific as to say that the superstructure of a certain bridge shall be made of wood.

Quality in cements depends essentially on correct chemical combination of the proper elements, hard burning, and fine grinding; the strength depending altogether on the amount of lime contained, the greater the lime chemically combined, the greater the strength.

The flexible items of cost in cement manufacturing are burning and grinding, and as the cost of grinding is in almost direct proportion to the amount of fuel used in burning, it is a great temptation to some manufacturers to underburn their cement, as this saving of fuel in burning means in addition a very large saving in the cost of grinding.

Let us consider what are the qualifications of a perfect Portland cement. It must be

First—Absolutely safe, uniform in quality, not cracking or swelling under the boiling test.

Second—Of great strength when mixed with large proportions of sand.

Third—Very slow setting to allow sufficient time for working, and for the necessary delays certain to be met with in actual work between the mixing box and the final resting place of the mortar or concrete.

Fourth—Quick hardening, obtaining maximum strength in shortest possible time.

Fifth—Uniform in color.

Testing is of absolute importance. Soundness being the first requisite, the boiling test should be required to determine stability and constancy of volume, as immersion in steam and boiling water from 20 to 24 hours brings about nearly the same condition in the mortar or concrete as does years of time under the conditions existing in actual construction.

Chemical analysis should be made when possible to determine presence of impurities, and also to learn if correct elements have been used and in proper proportion.

The greatest stress should be laid upon fine grinding, as no part of a barrel of Portland cement is of any cementing value except that which has been ground to a flour (approximately what will pass through a No. 200 sieve).

At least 40 per cent of each barrel of most English cements and 30 per cent of each barrel of many German cements are of no more value than so much good sand.

This question is receiving the attention of many cement manufacturers, particularly of those in this country, so it is possible to-day

to obtain cements that are 90 per cent fine on a sieve of 40,000 holes to the square inch.

Unsatisfactory results will be had from laboratory tests for strength unless the air and water are kept at a nearly uniform temperature during time of making briquettes, and until they are set. The setting of Portland cement being a chemical action, it is assisted very greatly by heat, and it is advisable to have the temperature between 65 and 70.

Freezing is always injurious to Portland cement before setting, but it is not seriously so, unless frequent freezing and thawing takes place during setting.

Portland cements are invariably injured by retempering.

Specifications should provide for the cement and sand to be mixed thoroughly together dry, then add only sufficient water to insure proper consistency. For concrete prepare mortar in same manner and add proportion of stone, turning this at least three times, twice as many would be better, so in order, if possible, to have each piece of stone enveloped with the mortar.

The fact that tensile tests with the inch square briquette vary so greatly when made under exact and similar conditions, and from the same sample of cement, proves conclusively that the present method of testing is far from perfect. Standard sand, viz., crushed quartz of fineness between a 20 and 30 sieve has over 40 per cent of voids, so it is impossible for the cement when mixed in proportions, 3 to 1, to fill the voids, and as the rules now in general use provide for simply pressing into the molds by the thumbs, it is quite probable that owing to the inability of this quality of sand to adjust itself compactly, the voids in the finished briquette vary materially. This variation, coupled with the personal equation and the inaccuracy of the testing machine, is the cause for much of the lack of uniformity, and yet, in the opinion of many engineers, the cement alone is chargeable with the uneven results obtained.

Too much stress cannot be laid upon the necessity of filling the voids in concrete; therefore, sufficient mortar should be provided to surely accomplish this end.

CEMENT AND CEMENT MORTARS.

By Thos. T. Johnson, M. W. S. E.

1. A general statement of the relative qualities of the several Portland and natural cements at present in the market cannot be made. The variety is numerous, and what is of direct interest, it is and recently has been becoming discouragingly numerous. This is particularly true of Portland cements. Considering the "tricks of the trade," as applied to selling cement, the consumer now and henceforth must exercise more than usual care in selecting his material. Quite recently the writer had occasion to examine a brand of Portland cement, the result of the tests being expected to form the basis of a sale, but the samples submitted hardened so rapidly, even with the use of water to the extent of 30 per cent of the weight of the

cement, that it was scarcely practicable to make a briquette. The briquettes made showed very low tensile strength. Other brands examined, including American, English, German, Danish, etc., have developed a wide variation in quality.

2. The testing of cements is useful in just the degree that the consumer is ignorant of the quality of the material he is using. At the present time, if the consumer knows where the cement comes from and by whom made, there are brands of cement which for certain purposes may be used without testing. This is particularly true of certain Portland cements which are manufactured so far from the market that the product cannot be adjusted to the test required, and the quality of which is not dependent on certain natural conditions difficult for the manufacturer to control. With reference to cements in general, it may be said that resort to testing is necessary to determine whether a suitable material is being secured, and no specification should be written that does not provide for an ample test.

3. Cement fails to be satisfactory for several reasons: (1) It may lack strength; (2) it may not be durable; (3) it may not be easy to use.

(1) Tests are usually made for tensile strength, but it is an open question whether it would not be better to include, or perhaps to rely solely on, tests for bending, crushing, or shearing. The stumbling block in the way of tests for strength is the fact that the material does not attain its ultimate strength within a year or even more. It is now recognized that a cement may show a comparatively low strength in seven days, a month or three months, and still be a superior cement at the end of a year. Indeed, it seems with some natural cements, at least, that, by manipulating the manufacture, a large strength may be developed at an early age at the expense of proving an inferior cement at long ages. It being utterly impracticable to make long-time tests before using the material, in nearly all cases, it may be said that tests for tensile strength answer all purposes, and will until the makers can produce more uniform material. The tensile strength that should be specified should be determined after making a general examination of the method of manufacture and general history of the cement to be used. This test, of course, proves hydraulicity.

(2) Tests for durability are difficult to determine because all the reasons that cause cement to fail are not known, and herein lurks a danger in using products not having been tried by years of use. The best test is found in the history of the particular kind of cement that is to be used. If the cement has no history, then inferences may be drawn by analogy, some similar cement being used as a standard. The tests for free quicklime are wise and familiar. The ability of a cement to resist climatic influences is little understood and it does not seem practicable to specify on that point. The same is true of chemical agencies in atmosphere and water and other substances near the cement, except, of course, that the influence of oily and other organic matters is known to be destructive.

(3) The ease with which cement can be used is governed mainly

by its rapidity of setting and specifications should be drawn to adjust the rate of setting to the degree of strength required at an early age and the rapidity of working. It may be that a more full knowledge of the subject may sometime develop a way of specifying what effect retempering shall have on a cement.

Tests for fineness are necessarily an adjunct to test for strength and qualification for mortar making.

(4) Tests of tensile strength of neat cement should record the kind of cement, the brand, where made, the fineness, the weight of water and cement used in a briquette, the temperatures affecting the operation, the age in air and water, the strength, the method of preparing and caring for the briquette and remarks as to the attending circumstances.

The method of preparing the briquette involves more room for difference of opinion than any other element involved. Uniformity of results is the end to be secured, and elimination of the personal equation of the maker. A variety of machines have been invented for the purpose, and various processes adopted. When short-time tests are being made the quantity of water entering a briquette is all important, and likewise when long-time tests are made, only in a less degree. Next to the quantity of water used, its thorough incorporation with the cement is important. Uniformity of results are necessarily difficult to obtain when but little water is used, for it is so easy to have briquettes compacted in various degrees. It occurs to the writer that perhaps the most satisfactory results will follow by using sufficient water to secure a plastic paste, the mixture being worked sufficiently to destroy all globules or lumps that form when not sufficiently worked. The paste thus prepared, when put in the molds, should be sufficiently soft so that thumb pressure will compact it as thoroughly as it can be compacted. The amount of water thus used will give pastes having a consistency even stiffer than mortar as ordinarily used in practice. During the past year the writer has directed six or eight briquette makers and by making comparisons cannot discover that there is any difference in their work, and furthermore, that any intelligent young man can be taught the art of briquette making in the course of one or two weeks.

The quantity of water to be used varies quite widely, even for a given brand of cement—especially natural cements. After a little practice the briquette maker can tell by ocular inspection, after having made two or three briquettes, what amount is proper. It is a good plan, however, to make up a series of briquettes from a given cement, with various percentages of water, before undertaking regular tests. These may be broken in one day, seven days, or in longer times, according to the time available. Such series should be made frequently when large lots of cement are being tested, and the results, taken in conjunction with current tests involving but one amount of water, will enable a much more intelligent comparison of various tests than would otherwise be the case.

Tests of the tensile strength of mortars should record, in addition to the items enumerated for neat cement, the fineness of the

sand, its mechanical and chemical state, its origin and the weight of dry sand entering a briquette. The same suggestion as to preparing briquettes will apply as for neat cement. It would be a good thing if the relative weights of cement and sand used could be standardized. The usual method of using one to one or two to one mixtures is too indefinite. And when weights, rather than volumes of materials, are used, the results are not satisfactorily comparable when different observers use different ratios.

5. The influence of the amount of water used in making a briquette is well illustrated by the following records: Tables XV, XVI, XVII and XVIII, appended, prepared from tests made for the Sanitary District of Chicago during the past year.

6. The effect of low temperatures on the setting and ultimate strength of cement mortars is a comparatively unexplored field. There are no end of examples of good masonry work constructed at very low temperatures, salt being used in the mortar, sand being heated, and various expedients adopted for protection. On the other hand there are plenty of failures under similar conditions. It is safer, to say the least, to execute cement mortar work at the higher temperatures.

7. The effect of regauging, or temporary cement mortar, is variously estimated. It is highly probable that, under certain conditions, no serious injury follows a judicious tempering, but that the process can result in essential destruction of the mortar. The following tests, in Tables XVII and XX, appended, made under direction of the writer, for the Sanitary District of Chicago, are interesting in this connection.

The tests in Table XX were made with a view to subjecting the cement to extremely trying conditions, but still conditions apt to occur in practice. A batch of the paste or mortar was made up, and by frequent additions of water was tempered and retempered during a period of one hour, its consistency being always kept about suitable to be handled with a trowel. At the end of 10, 20, 30, 45 and 60 minutes briquettes were made, as indicated by the table.

The conclusion is, that with Louisville cement, at least, repeated regauging has a bad effect, essentially destroying the material, but that one, or even two regaugings may not do a great amount of injury. In any event it is better, if practicable, to use the cement before it has stiffened to an extent that will not permit its use with a trowel.

The writer had occasion, in September, 1894, to inspect the first retaining wall work done by the Sanitary District. The contractor was mixing the mortar in a manner that suited him best, which involved the filling of a large mortar box with the materials and flooding the whole with water, then hoeing it into a paste leisurely and using the mortar even more leisurely. The last of the batch was put in the wall about forty-five minutes after mixing. Louisville cement was being used. After watching the operation for a while, proper proportions of cement and sand, the same as was used by the

contractor, were mixed to a mortar and immediately placed in a wooden box, making a briquette about 8 inches by 8 inches by 4 inches. A portion of mortar was then taken from the contractor's mortar box, where it had been for about 45 minutes, and this was made into another briquette the same size as the first. The two were placed side by side and kept in the office until recently, when, being fifteen months old, they were examined. The mortar made and placed quickly was very hard, like a stone, but that taken from the mortar boxes was pliable and easily crumbled between the fingers.

8. The following is extracted from specifications prepared by the writer for the preparation and use of cement mortar for the Sanitary District of Chicago, natural cement being used:

(a) "Measure sand portion in dry mixing box.

(b) "Measure cement on top of sand.

(c) "Overcast twice with shovel, or more often if necessary.

(d) "Cast dry mixture of cement and sand through No. 5 sieve or screen.

(e) "Be sure incorporation is fully accomplished before adding any water.

(f) "Add water at part of wet mixing box remote from screen.

(g) "Add water slowly and gradually to prevent washing.

(h) "Hoe dry mixture slowly into water, avoiding any stirring further than to uniformly wet the mixture.

(i) "Conform mortar mixing to progress of the work so no mortar goes into wall after having been wet fifteen minutes."

Probably the greatest fault with ordinary mortar mixing is in incorporating the sand and cement, particularly if the sand is damp—and it almost always is. Shovel turning does not and cannot accomplish a satisfactory result, nor indeed does any other method that does not divide the materials and cause them to fall together to form a mass. After the sand and cement have been shovel-turned twice, as called for by the specification, a partial mixture has been effected, but small masses of sand will be found in which there is no cement. But when a shovel full of the material in this state has been cast against the wire screen it is divided and scattered, and in falling to the box the result is a quite thorough incorporation of the material. Furthermore, this method of mixing is less expensive than shovel turning, as is attested by the willing and cheerful manner in which the contractors accepted the requirement.

10. The extent to which cement mortar plasters can be relied upon to adhere to cement mortar concrete seems to depend on several things. Ample evidence is found in sidewalk practice, where the surfaces are plane and horizontal, and where the cement is Portland both in the mortar and the concrete. The sea wall on the shore of Lake Michigan at Chicago, and extending half a mile or more south from Lincoln Park, is a notable failure. Here, however, while the cement in both concrete and mortar is Portland, the surfaces are for the most part curved. The original plaster covering seems to have separated almost entirely from the concrete base,

TABLE No. XX.

Brand: Louisville. (Mixture from six carloads.)

Remarks: Tests to determine the effect of allowing mortar to be mixed a given time before being put into the moulds. The mortar was worked over with trowel during the time elapsing between the application of water and moulding into briquettes.

N. B.—The proportions of water given above are about those used at first application of water. Throughout this test the mortar was kept at about the consistency used in actual work, requiring the addition of extra water at intervals.

Brand	Cement No. 50 Sieve	No. 80 Sieve	No. 100 Sieve	Weight in Pounds per Cu. Ft. Loose	Times after the application of water before the mortar was put into the moulds	Sand Kind	No. 20 Sieve	No. 30 Sieve	No. 50 Sieve	No. 80 Sieve	No. 100 Sieve	% by Weight of Dirt	Sand Weight per Cu. Ft. Loose	Neat Cement	Neat Water	1:1 By Volume Cement	Sand	Water	1:2 By Volume Cement	Sand	Water
Louisville	93.5	87.5	84.8	48.0	0 min.	K. Ice Co	68.0	55.2	31.9	5.6	1.2		100.3	100	38	32.4	67.6	24.0	19.3	80.7	21.0
"	"	"	"	"	10 "	"	"	"	"	"	"		"								
"	"	"	"	"	20 "	"	"	"	"	"	"		"								
"	"	"	"	"	30 "	"	"	"	"	"	"		"								
"	"	"	"	"	45 "	"	"	"	"	"	"		"								
"	"	"	"	"	60 "	"	"	"	"	"	"		"								

Average tensile strength in pounds per square inch at the age of:

Time	1:3	1 Day Neat No. of Briquettes	Breaking Stress	7 Days Neat No.	Stress	7 Days 1c. to 1s. No.	Stress	7 Days 1c. to 2s. No.	Stress	7 Days 1c. to 3s. No.	Stress	28 Days Neat No.	Stress	28 Days 1c. to 1s. No.	Stress	28 Days 1c. to 2s. No.	Stress	28 Days 1c. to 3s. No.	Stress	3 Months Neat No.	Stress	3 Months 1c. to 1s. No.	Stress	3 Months 1c. to 2s. No.	Stress	3 Months 1c. to 3s. No.	Stress
0 min.	Ave of full set	15	124.1	15	126.7	15	39.7	15	5.1			15	206.0	15	95.3	15	13.0			15	273.1	15	238.9	15	155.0		
	" " act breaks					"	"	7	11.0					"	"	14	46.0					"	"				
10 "	" " full set					15	45.3	12	14.8					15	96.6	15	39.3					15	240.7	14	178.0		
	" " act breaks					"	"	14	15.9					"	"	14	42.1										
20 "	" " full set					15	20.6	15	2.7					15	76.3	15	31.6					14	194.8	15	93.1		
	" " act breaks					"	"	3	13.6					"	"	11	43.1										
30 "	" " full set					15	18.4	15	0.0					15	71.0	15	21.3					14	191.6	15	80.2		
	" " act breaks					"	"	0	0.0					12	84.7	9	35.5					"	"	11	109.4		
45 "	" " full set					15	16.0	15	0.0					15	67.0	15	14.0					15	188.9	15	28.1		
	" " act breaks					13	18.4	0	0.0					11	91.3	5	45.0					"	"	7	60.3		
60 "	" " full set					15	12.0	15	0.0					15	58.3	15	8.2					15	191.3	15	25.7		
	" " act breaks					13	13.9	0	0.0					11	79.5	5	24.6					"	"	4	96.5		

TABLE No. XXI.

Remarks: Tests of the adhesive strength between Louisville and Portland cements. One-half of each briquette Louisville and the other half Portland.

N. B.—All the briquettes were kept in air the time of test.

N. B.—In the tests marked "Fresh" the Louisville end of the briquette was molded first and the Portland end added immediately after. In those marked "7 d. old" the Louisville ends consisted of half briquettes broken at the age of 7 days (in air). Portland ends were added a day or two after breaking.

Brand	Cement No. 50 Sieve	No. 80 Sieve	No. 100 Sieve	Weight per Cu. Ft. Loose	Proportions of the Louisville half of briq.	Sand Kind	No. 20 Sieve	No. 30 Sieve	No. 50 Sieve	No. 80 Sieve	No. 100 Sieve	Sand Weight	Neat Cement	Neat Water	1:1 Cement	Sand	Water	1:2 Cement	Sand	Water	1:3 Cement	Sand	Water
Louisville and	92.6	87.1	81.3	54.9	Neat, Fresh; 7 d. old	K. Ice Co	80.1	67.1	41.5	7.2	1.4	102.9	100 (Louisville)	35.0 (Louisville)	31.8 (Louisville)	65.2 (Louisville)	16.0 (Louisville)						
Old Portland.	100.0	99.5	96.0	76.6	1:1, Fresh								100	18.2	42.7 (Portland made with Louisville fresh)	57.2	11.3	27.1	72.9	9.0	19.9	80.1	7.6
					1:1, 7 d. old								100	23.8	42.7 (Portland made with Louisville 7 day old)	57.2	13.2	27.1	72.9	11.1	19.9	80.1	10.9
[illegible] Portland.	99.4	98.3	92.3	83.3	Cement is a mixture of two sample bags	K. Ice Co	56.5	48.5	31.0	9.8	2.8	106.7	100	22.5	43.8	56.2	14.2	28.1	71.9	11.4	20.7	79.3	9.9

The proportions in the following columns refer to Portland ends of briquettes.

	1 Day No.	Stress	7 Days Neat No.	Stress	7 Days 1:1 No.	Stress	7 Days 1:2 No.	Stress	7 Days 1:3 No.	Stress	28 Days Neat No.	Stress	28 Days 1:1 No.	Stress	28 Days 1:2 No.	Stress	28 Days 1:3 No.	Stress	3 Months Neat No.	Stress	3 Months 1:1 No.	Stress	3 Months 1:2 No.	Stress	3 Months 1:3 No.	Stress	
Louisville and Portland			10	136.0	10	142.0	10	62.5	10	102.0	10	164.2	10	147.9	10	98.4	10	113.8	10	171.8	10	129.3	10	164.0	10	156.3	Averages of full sets.
			9	161.0	9	157.8	8	78.1	9	113.3	"	"	"	"	"	"	"	"	8	214.8	"	"					actual breaks.
			10	75.0	10	61.5	10	14.5	10	2.5	10	124.2	10	27.7	10	16.8	10	0.0	10	86.6	10	16.0	10	5.8	10	4.1	full sets.
			"	"	8	80.6	4	37.5	2	12.5	"	"	7	39.6	5	3.6	0	0.0	9	96.2	6	26.7	4	14.5	3	13.7	actual breaks.
			10	89.5	10	136.0	10	155.0	10	119.0	10	177.1	10	164.6	10	191.1	10	153.9	10	110.2	10	153.8	10	161.0	10	165.4	full sets.
			8	111.9	"	"	"	"	"	"			"	"	"	"	"	"	"	"	"	"	"				actual breaks.
			10	145.5	10	104.0	10	40.0	10	47.0	10	80.1	10	79.6	10	28.6	10	23.6	10	46.0	10	36.6	10	31.9	10	21.0	full sets.
			"	"	"	"	7	57.1	8	58.8	"	"	9	88.4	8	35.7	7	33.7	"		8	15.8	"	"	8	26.3	actual breaks.
Portland	25	171.2	30	369.5	14	305.0	15	247.3	15	182.0	25	488.7	15	424.5	15	321.4	15	258.8	25	524.0	15	498.1	15	370.1	15	351.1	

TABLE No. XV.

Remarks: N. B.—The above analysis applies to the cement used in the following mortar tests, not to that used in the 7-day neat tests. The cement for the mortar samples was a mixture from several carloads, about three-fourths of which averaged over 180 pounds and one-fourth about 125 pounds in regular 7-day neat tests. Neat samples (7 days) were made from a rejected carload, C. R. I. & P., 6402.

Tests to show the effect of varying the % of water.

Brand	Cement No. 50	No. 80	No. 100	Weight	Sand Kind	No. 20	No. 30	No. 50	No. 80	No. 100	Sand Weight	Neat Cement	Neat Water	1:1 Cement	1:1 Sand	1:1 Water	7 Days Neat No.	Stress	7 Days 1:1 No.	Stress	28 Days 1:1 No.	Stress	3 Months 1:1 No.	Stress
Utica (Clark)	93.2	82.9	78.7	56.3	K. Ice Co	77.5	64.4	40.5	9.9	2.9	102.3			35.5	64.5	10			10	51.6	10	90.6	10	115.6
"					"	"	"	"	"	"		100	24	"	"	12	30	91.1	10	40.4	10	103.3	10	129.3
"					"	"	"	"	"	"		100	28	"	"	14	30	102.0	10	85.0	10	174.6	10	207.6
"					"	"	"	"	"	"		100	32	"	"	16	30	121.0	10	86.2	10	215.6	10	269.5
"					"	"	"	"	"	"		100	36	"	"	18	30	131.3	10	83.0	10	219.2	10	285.7
"					"	"	"	"	"	"		100	40	"	"	20	30	97.0	10	63.5	10	170.4	10	214.2
"					"	"	"	"	"	"		100	44	"	"	22	30	68.5	10	56.2	10	159.0	10	202.1

TABLE No. XVII.

Tests with varying % of water.

Cement was from a barrel sent by Dickeson Cement Co. for tests.

Brand	Cement No. 50	No. 80	No. 100	Weight	Sand Kind	No. 20	No. 30	No. 50	No. 80	No. 100	Sand Weight	Neat Cement	Neat Water	1:2 Cement	1:2 Sand	1:2 Water	1:3 Cement	1:3 Sand	1:3 Water	1 Day No.	Stress	7 Days Neat No.	Stress	7 Days 1:2 No.	Stress	7 Days 1:3 No.	Stress	28 Days Neat No.	Stress	28 Days 1:2 No.	Stress	28 Days 1:3 No.	Stress
Alpha Portland.	99.6	95.3	90.0	79.9	K. Ice Co	84.3	73.0	42.0	9.8	4.2	97.0	100	11	Volumes 1	2					17	73.1	15	175.9					15	333.7				
"	"	"	"	"	"	"	"	"	"	"	"	100	13	Weights						12	68.3	15	234.3					15	246.7				
"	"	"	"	"	"	"	"	"	"	"	"	100	15	26.6	73.4	6				14	90.0	15	179.8	10	116.1			15	309.3	10	181.6		
"	"	"	"	"	"	"	"	"	"	"	"	100	17	"	"	8				15	113.8	15	320.4	10	155.4			15	397.0	10	255.7		
"	"	"	"	"	"	"	"	"	"	"	"	100	19	"	"	10	21.6	78.4	9.1	15	98.5	15	383.2	15	179.5	14	116.5	15	502.7	15	293.6	15	223.3
"	"	"	"	"	"	"	"	"	"	"	"	100	21	"	"	12				10	64.8	15	399.7	15	153.1			15	496.6	10	304.2		
"	"	"	"	"	"	"	"	"	"	"	"	100	23	"	"	14				15	101.2	15	400.5	10	142.2			15	677.9	10	280.3		
"	"	"	"	"	"	"	"	"	"	"	"	100	25	"	"	10				10	80.9	14	343.5	10	165.8			15	463.4	10	288.5		
"	"	"	"	"	"	"	"	"	"	"	"	100	27	"	"	18				15	50.4	15	335.9	10	179.4			15	456.6	10	347.1		
"	"	"	"	"	"	"	"	"	"	"	"	100	29							13	86.8	15	301.0					15	430.3				
"	"	"	"	"	"	"	"	"	"	"	"	100	31							12	50.8	15	300.9					16	393.1				

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TABLE No. XVI.

CEMENT USED		Analysis for Fineness. % Passing		REMARKS.	SAND USED. Analysis for Fineness and Dirt. % Passing.						Ratio by Weight. Neat Cement.		1:1 By Volume.			1:2 By Volume.		
Brand	Numbers of Samples.	No. 50 Sieve.	No. 100 Sieve.		No. 20 Sieve.	No. 30 Sieve.	No. 50 Sieve.	No. 80 Sieve.	No. 100 Sieve.	% by Weight of Dirt.	Cement.	Water.	Cement.	Sand.	Water.	Cement.	Sand.	Water.
Louisville.											100	24						
"				Homogeneous mixture of cement from three carloads, thoroughly mixed.							100	28						
"				1-day samples set 1 hr. in air & 23 hrs. in water							100	32						
"				Other " " 24 hrs. " " remainder of time in water.							100	36						
"											100	40						
"											100	44						
"											100	48						

Brand	Average Tensile Strength per Square Inch in Pounds at the Age of 1 Day. Neat. No. of briquettes.	Breaking Strain.	7 Days. Neat. No. of briquettes.	Breaking Strain.	7 Days. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	7 Days. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	28 Days. Neat. No. of briquettes.	Breaking Strain.	28 Days. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	28 Days. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	3 Months. Neat. No. of briquettes.	Breaking Strain.	3 Months. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	3 Months. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	6 Months. Neat. No. of briquettes.	Breaking Strain.	6 Months. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	6 Months. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	1 Year. Neat. No. of briquettes.	Breaking Strain.	1 Year. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	1 Year. 1 c. to 2 s. No. of briquettes.	Breaking Strain.
Louisville.	15	73.3	15	92.6					15	133.7					15	171.6					15	231.8										
"	15	93.8	15	125.0					15	152.3					15	200.4					15	254.2										
"	15	124.8	15	151.8					15	196.0					15	249.9					15	31[illegible].7										
"	15	101.3	15	147.3					15	227.3					15	254.6					15	334.9										
"	15	79.5	15	109.6					15	199.0					15	253.2					15	276.9										
"	15	50.8	15	84.7					15	171.3					15	236.6					15	268.5										
"	15	42.0	15	57.7					15	125.7					15	217.3					15	236.7										

TABLE No. XVIII.

Brand	Numbers of Samples.	No. 50 Sieve.	No. 100 Sieve.	Remarks.	No. 20 Sieve.	No. 30 Sieve.	No. 50 Sieve.	No. 80 Sieve.	No. 100 Sieve.	% by Weight of Dirt.	Neat Cement. Cement.	Water.	1:1 Cement.	Sand.	Water.	1:2 Cement.	Sand.	Water.
.. n Portland.	Sample Bag.	99.5	93.5								100	10						
"	" "	"	"								100	12						
"	" "	"	"								1 0	14						
"		"	"								100	16						
"		"	"								100	18						
"	"	"	"	Tests to show the effect of varying % of water.							100	20						
"	" "	"	"								100	22						
"	" "	"	"								100	24						
"	" "	"	"								100	28						
"	" "	"	"								100	28						
"	" "	"	"								100	30						

Brand	1 Day. Neat. No. of briquettes.	Breaking Strain.	7 Days. Neat. No. of briquettes.	Breaking Strain.	7 Days. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	7 Days. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	28 Days. Neat. No. of briquettes.	Breaking Strain.	28 Days. 1 c. to 1 s. No. of briquettes.	Breaking Strain.	28 Days. 1 c. to 2 s. No. of briquettes.	Breaking Strain.	3 Months. Neat. No. of briquettes.	Breaking Strain.
.. n Portland.	5	79.8	5	126.4					5	180.0					5	238.0
"	5	108.7	5	171.4					5	221.0					5	331.4
"	5	107.8	6	230.0					5	302.3					5	392.2
"	5	198.6	5	306.0					5	374.2					5	420.8
"	5	227.8	6	343.0					5	424.4					5	353.2
"	5	195.0	6	438.0					5	47 .0					5	159.0
"	5	187.0	5	412.0					5	535.0					5	646.8
"	5	142.5	5	295.9					5	424.0					5	494.8
"	5	129.6	6	342.6					5	437.8					5	507.2
"	4	90.0	4	346.2					5	423.4					3	561.0
"	Che	cked.	2	317.0					2	436.0					2	584.0

TABLE No. XIX.

Brand	Numbers of Samples.	Analysis for Fineness.	Remarks.	No. 20 Sieve.	No. 30 Sieve.	No. 50 Sieve.	No. 80 Sieve.	No. 100 Sieve.	% by Weight of Dirt.	Neat Cement. Cement.	Water.	1:1 Cement.	Sand.	Water.	1:2 Cement.	Sand.	Water.
Louisville.	*780-840	See columns for sand.	Refuse from briquettes made from samples 780-840	62.5	61.4	41.8	32.3	29.2		100	28						

Brand	1 Day. Neat. No. of briquettes.	Breaking Strain.	7 Days. Neat. No.	Breaking Strain.	7 Days. 1 c. to 1 s. No.	Breaking Strain.	28 Days. Neat. No.	Breaking Strain.	28 Days. 1 c. to 1 s. No.	Breaking Strain.	3 Months. Neat. No.	Breaking Strain.	3 Months. 1 c. to 1 s. No.	Breaking Strain.	6 Months. Neat. No.	Breaking Strain.	6 Months. 1 c. to 1 s. No.	Breaking Strain.	1 Year. Neat. No.	Breaking Strain.	1 Year. 1 c. to 1 s. No.	Breaking Strain.
Louisville.	1	13.0	3	49.0	1	13.0	3	76.3	2	45.0	2	159.0	1	130.0	2	144.5	1	176.0	2	149.0	1	187.0

* This refuse, which was at least a day old, was granulated to pass a No. 8 sieve. The fineness is given above in the columns for analysis of sand. Briquettes were allowed to set about 48 hours in air and then placed in water. The 1:1 briquettes were made of residue from briquettes made 22 hours before, and the fineness of the sand used in the original samples was as follows: Per cent. passing sieves, No. 20-77.5; No. 30-60.1; No. 50-34.3; No. 80-6.7; No. 100-1.6. By refuse is meant the surplus of mortar above that required to make a briquette. This surplus, as briquettes for regular tests are made, is brushed to one side in a heap, and the mass of stuff is termed refuse.

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and where it has been replaced or patched this plaster, too, has in a radical degree failed to adhere.

On the other hand, a concrete dam, forming part of the works of the Sanitary District of Chicago, 400 feet long, and having about 1,000 square yards of surface, not including stone coping of dam, has been successfully covered with a Portland cement plaster, the heart of the dam being constructed of natural cement concrete. The plastering was not put on until a winter and part of a summer had passed after the rest of the dam was completed. Before being placed a stream of water from a one (1) inch nozzle, with about 20 pounds nozzle pressure, was used to thoroughly wash the surface, said surface having previously been well rubbed with a wire broom. The plaster was put on quite wet so as to insure its entering well into the irregularities of the concrete surface. It is highly probable, in this case, that the bond of the plaster to the exposed stone in the concrete would be sufficient for success even if the bond between the two cements was imperfect.

Success in such operations will be much facilitated if the concrete surface be very rough. If the concrete surface be smooth it is highly probable that the different expansions of the two materials will cause a separation at the surface of contact, if, indeed, certain chemical actions do not effect the same result. The writer has directed, for the Sanitary District of Chicago, a series of experiments for information as to the adhesion of Portland cement mortar to natural cement mortar. Briquettes were made, one end being made of natural cement mortar and the other end of Portland cement mortar. They were made in two ways:

(1) One end of the mold, to its middle, was filled with Louisville cement mortar and allowed to take an initial set. Then the rest of the mold was filled with the Portland cement mortar. Results are in Table XXI.

(2) Louisville cement mortar briquettes were made and broken at the end of seven days. The half briquettes thus secured were placed back in the molds and the rest of the mold filled out with the Portland cement mortar. Results are in Table XXI.

It appears that the best results were obtained by the use of the Portland cement mortar against the fresh Louisville cement mortar, but this may be accounted for, in part at least, by the greater difficulty in making the briquettes involving the older Louisville cement mortar. The pieces could not be set back in the molds as solidly as originally and consequently the Portland cement mortar could not be as thoroughly compacted against them as might be desired. In any event, the results are not very encouraging for the possibility of successfully bonding the two mortars when the surfaces of contact are quite smooth.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

EXPERIMENTS ON THE ELASTICITY OF CONCRETE.

BY C. BACH.

(*Zeitschrift des Vereines Deutscher Ingenieure, 1895, p. 489.*)
(*Abstract by P. W. B., Proc. Inst. of C. E. Vol. CXXII.*)

In tabulating and stating the results of his investigations on the strength of concrete, the author, who has during the past few years carried out several exhaustive series of experiments on the strength of various materials, calls attention to the fact that in most of the hitherto recorded experiments on concrete the test blocks have been of such small dimensions that it must be evident that the component materials, if mixed on a practical scale (i. e., such as they would be in the actual execution of any work), could not possibly afford results of any uniform or comparative accuracy; while if specially selected and packed to form a small block in a manner not applicable in actual construction the result cannot afford any reliable information as to the practical strength of the material. A further point in which it appears needful to supplement previous records is in clearly stating the variation between temporary and permanent set; in other words, the elasticity of the material.

In order to secure tests upon a practical and reliable basis, the author had thirty-six blocks prepared, each 9.84 inches in diameter and of an average length of 39.37 inches. The following were the six mixtures experimented upon:

I.	1 of Portland cement,			2 1-2 sand, 5 gravel.
II.	1	"	"	2 1-2 sand, 5 limestone shingle.
III.	1	"	"	7 1-2 sandy gravel.
IV.	1	"	"	3 sand, 6 gravel
V.	1	"	"	3 sand, 6 limestone shingle.
VI.	1	"	"	9 sandy gravel.

Six test blocks were made in each of these mixtures, three being with Portland cement from Blaubeuren and three with cement from Lauffen-on-Neckar. On passing the cement through a sieve of 5,600 meshes to the square inch, the residue from the former was 1.9 per cent and from the latter 3.3 per cent. The normal test at twenty-eight days after mixing (one day in air and twenty-seven in water) gave the following respective breaking weights:

Blaubeuren	cement	concrete,	362.6	lbs.	per	square	inch.
Lauffen	"	"	301.5	"	"	"	"

The measurements were taken on a length of 29.5 inches, and the following was the arrangement adopted with each block: The two ends of the block having been planed to absolutely parallel faces, two metal rings were securely clamped round the block at a distance

of 29.5 inches center to center. The lower ring carried a small block dished on the upper surface to form a bearing for a vertical steel bar, the upper end of which just came in contact with the short-arm of a lever mounted on a plate carried on the upper ring, when the said lever was in its normal position of rest at right angles with the axis of the test block. The long arm of this lever was fitted with a rack, giving motion to a pinion, on the spindle of which was mounted a needle-pointer registering on the face of a large-graded sector. In the normal position as above described the pointer indicated zero. The compression of the block, bringing the rings closer together, caused the freely moving bar to push the short arm of the lever upwards, and the pointer (through the rack-and-pinion motion) to rise on the sector. The instrument was so proportioned that for 1 millimeter compression on the test block the pointer would traverse 300 millimeters on the sector. The scale being graduated to 1-10 millimeter (0.0039 inch) divisions, the readings were equivalent to 0.000013 inch on the block, i. e., to $\frac{1}{2,250,000}$ of the test-length under measurement. The measurements were taken in duplicate on each side of the block, so that any inequality was distinctly recorded. Each successive load was applied and removed at 1 1-2 minute intervals until the permanent and temporary set remained constant under three consecutive loadings; in other words, until the definite limit of elasticity was reached for each load. The next increase of load was then made, and so on. The subjoined table, recording the successive variations in one block under repeated applications of the same load, and under increasing loads, illustrates the method pursued throughout the experiments.

Load.		Number of times loading and unloading repeated until no further variation.	Percentage of Contraction.		
Total (tons)	Lbs. per square inch.		Temporary.	Permanent.	Total.
4	112.3	4[1]	Varying from 0.188	0.027	0.215
			to 0.193.	0.028	0.221
8	224.7	5	" from 0.412	0.052	0.464
			to 0.425.	0.058	0.483
12	337.0	5	" from 0.662	0.083	0.745
			to 0.687.	0.092	0.779
16	449.4	6	" from 0.920	0.132	1.052
			to 0.967.	0.152	1.119
20	561.7	8	" from 1.207	0.190	1.397
			to 1.272.	0.238	1.510

The maximum figures for each load represent therefore the ultimate elastic strength of the material.

[1] I. e., four repetitions of loading and unloading, with increasing percentage of contraction, then three repetitions without any variation in effect; and similarly with the following series.

The following table summarizes the results of the series of experiments with the Blaubeuren cement concrete blocks. (The second column refers to the number of the mixture, the letters *a b c* indicating the successive three blocks of each mixture.)

PERCENTAGE CONTRACTION OF BLAUBEUREN CEMENT CONCRETE UNDER VARYING LOADS.

Series of Experiments.	No. of Mixture and of Sample.	Nature of Set.	Contraction in Percentage of Test length. Test loads.					Co-efficient of Contract'n.	Ultimate Tenacity.
			4 T	8 T	12 T	16 T	20 T		
									Lbs. per sq. in.
1	Ic	Elastic or Temporary..	0.193	0.425	0.687	0.967	1.272		
		Permanent..	0.028	0.058	0.092	0.152	0.238		1,369.4
		Total.	0.221	0.483	0.779	1.119	1 510	1/306,000	
2	IIa	Temporary..	0.160	0.415	0.674	0.940	1.227		
		Permanent..	0.023	0.043	0 063	0.096	0.133		1,787.4
		Total	0.183	0.458	0.737	1.036	1.360	1/329,000	
3	IIb	Temporary..	0.153	0.340	0.685	0.943	1.233		
		Permanent..	0.056	0.092	0.127	0.165	0.217		1,983.7
		Total	0.209	0.432	0.812	1.108	1.450	1/386,000	
4	IIc	Temporary..	0.160	0.400	0.630	0.863	1.152		
		Permanent..	0.023	0.056	0 092	0.116	0.147		1,804.5
		Total	0.183	0.456	0.722	0.979	1.299	1/333,000	
5	IIIa	Temporary..	0.175	0.412	0 672	0.932	1 207		
		Permanent..	0.030	0.067	0.106	0.150	0.195		1,865.7
		Total......	0.205	0.479	0 778	1 082	1.402	1/343,000	
6	IIIb	Temporary..	0.172	0.378	0.593	0.832	1.073		
		Permanent..	0.018	0.037	0.060	0.088	0.123		2,009.3
		Total	0.190	0.415	0.653	0.920	1.196	1/350,000	
7	IIIc[1]	Temporary..	0 190	0.410	0.658	0.902	1.157		
		Permanent..	0.025	0.058	0 075	0 107	0.140		2,093.2
		Total......	0.215	0 468	0 733	1.009	1.297	1/316,000	
8	IVa	Temporary..	0.188	0 410	0.650	0.903	1.155		
		Permanent..	0.013	0.073	0.103	0.135	0.168		1,636.7
		Total......	0.201	0.483	0.753	1.038	1.323	1/315,000	

[1] See following table

PERCENTAGE CONTRACTION OF BLAUBEUREN CEMENT CONCRETE UNDER VARYING LOADS.—CONTINUED.

Series of Experiments.	No. of Mixture and of Sample.	Nature of Set.	Contraction in Percentage of Test length. Test loads. 4 T	8 T	12 T	16 T	20 T	Co-efficient of Contract'n.	Ultimate Tenacity.
									Lbs. per sq. in.
9	IVb	Temporary..	0.200	0.440	0.705	0.970	1.238		1,565.6
		Permanent..	0.037	0.068	0.088	0.135	0.183		
		Total.	0.237	0.508	0.793	1.105	1 421	$\frac{1}{296,000}$	
10	IVc	Temporary..	0.203	0.452	0 703	0.970	1.240		1,702.1
		Permanent..	0.032	0.053	0 080	0.103	0.128		
		Total	0.235	0.505	0.783	1.073	1.368	$\frac{1}{295,000}$	
11	Va	Temporary..	0.173	0.388	0.648	0.927	1.218		1,686.5
		Permanent..	0.010	0.037	0.067	0.108	0.145		
		Total	0.183	0.425	0.715	1.035	1.363	$\frac{1}{346,000}$	
12	Vb	Temporary..	0.183	0.412	0.652	0.942	1.235		1,722.0
		Permanent..	0.007	0.042	0.070	0.108	0.150		
		Total	0.190	0.454	0.722	1.050	1.385	$\frac{1}{327,000}$	
13	Vc	Temporary..	0.188	0.427	0 688	0.972	1.265		1,639.6
		Permanent..	0.027	0.045	0.085	0.120	0.172		
		Total......	0.215	0.472	0.773	1.092	1.437	$\frac{1}{315,000}$	
14	VIa	Temporary..	0.197	0.418	0.652	0.903	1.175		1,511.6
		Permanent..	0.005	0.030	0.057	0.093	0.147		
		Total	0.202	0.448	0.709	0.996	1.322	$\frac{1}{301,000}$	
15	VIb	Temporary..	0 188	0.395	0.623	0.867	1.127		1,666.6
		Permanent..	0.030	0.060	0.077	0.100	0.113		
		Total......	0.218	0 455	0.700	0.967	1.240	$\frac{1}{319,000}$	
16	VIc	Temporary..	0.165	0.363	0.573	0.802	1.032		1,962.4
		Permanent..	0.005	0.020	0.045	0.068	0.088		
		Total......	0.170	0.383	0.618	0.870	1.120	$\frac{1}{364,000}$	

As an illustration of the further series of tests up to the breaking point, the series of experiments with higher loads on block IIIc (see preceding table) may be quoted:

Load.		Percentage of Contraction.		
Tons, (Total.)	Pounds per square inch.	Temporary.	Permanent.	Total.
20	561.7	1.157	0.140	1.297
24	674.0	1.355	0.178	1.533
28	786.4	1.665	0.223	1.888
32	898.8	1.932	0.300	2.232
36	1,011.1	2.205	0.385	2.590
40	1,123.4	2.503	0.470	2.973
44	1,235.7	2.810	0.530	3.340
48	1,348.0	3.142	0.675	3.817
52	1,460.3	3.493	0.823	4.316
56	1,572.8	3.898	1.022	4.920
60	1,685.1	4.297	1.237	5.534
64	1,797.6	4.857	1.568	6.425
68	1,909.7	5.580	2.137	7.717
74	2,093 2	Breaking point.		

In the preceding series of experiments with Blaubeuren cement the maximum and minimum results as shown in the table, are:

Highest ultimate tenacity (2,093.2 lbs. per sq. in.) mixture No. III.

Lowest " " (1,369.4 lbs. per sq. in.) mixture No. I.

Least permanent set (0.088 per cent) mixture No. VI.

Greatest " " (0.238 per cent) mixture No. I

The series of blocks formed with cement from Lauffen-om-Neckar was tested in a precisely similar manner. The general results are inferior to the first series, and may be thus briefly summarized:

Highest ultimate tenacity, 1,616.8 lbs. per square inch.

General range of ultimate tenacity, from 881.6 to 1,279.8 lbs. per sq. inch.

Least permanent set (0.210 per cent) mixture No. II.

Greatest " " (0.555 per cent) mixture No. VI.

From the preceding summaries the important influence of the binding material is clearly evident upon both the temporary and permanent character of the concrete mass.

COMPARATIVE TESTS OF STEAM BOILERS WITH DIFFERENT KINDS OF COAL.

By Chas. E. Emery.

(*Abstract, Trans. Am. Soc. M. E., Vol. XVII.*)

The paper of Mr. Dean* criticises the standard code of 1886 from the fact that it provides to compare the efficiency of boilers by the actual evaporation per unit of combustible. The paper claims that "combustible, as well as coal, varies in heat value per pound;" and urges that boiler trials should be reported on the "basis of efficiency," which is defined to be "the ratio between the total heat which any given coal can generate by complete combustion, and that part of it which is absorbed by the water, and steam heated and generated." He adds: "There are two methods of obtaining the heat value of coal; one by burning a representative sample in some kind of oxygen calorimeter, and the other is to analyze the coal, and equate the elements with their heat values."

Additions may be desirable to the code of rules for testing boilers, but it is not at all evident that they will be in the direction indicated above. Conclusions drawn by reason from accepted elementary facts are not always correct, because the combinations, so easily made mentally, involve actually many unknown physical conditions. Many such conclusions are so evident that they are suggested again and again. For instance, nothing is apparently more reasonable than the recommendation in Mr. Dean's paper "to analyze the coal and equate the elements with their heat values," but it was known over 50 years ago that this method did not give the practical value of fuel for the purposes of generating steam.

Experimentally, hydrogen burned in oxygen has over four times the calorific value of carbon. It seems evident, therefore, that the value of the fuel should be greater, the larger the proportion of hydrogen it contains, but such is not the case. The evidence to the contrary was at an early date overwhelming, and it was claimed by many that the commercial value of coal of all kinds was practically proportioned to the carbon element alone. From the weight of evidence, it appears to the writer that this simple rule is, in a general sense, as nearly accurate as any other that has been suggested for a number of varieties of coal burned with ordinary apparatus and management.

It has also been suggested that the practical evaporation bears a definite relation to the proportion of "fixed combustible," or that remaining after the volatile matter in the coal has been distilled off; but from the weight of evidence it appears to the writer that this proposed rule is not generally applicable, though it should be borne in mind that the proportions of fixed and volatile combustible matter are used universally as a means of identifying and classifying different kinds of fuel. A well-established result of this classification is

*"Efficiency of Boilers: A Criticism of the Society's Standard Code of Reporting Boiler Trials." By F. W. Dean, Trans. Am. Soc. M. E., Vol. XVI.

that the evaporative efficiencies of anthracite and semi-bituminous coals containing less than 20 per cent. of volatile combustible are, in a general sense, nearly equal, independent of chemical composition; though, as a rule, the theoretical calorific value increases considerably, and the practical evaporation slightly, with the increase of volatile matter within these limits. On the contrary, as the proportion of volatile matter increases above such limits, the percentage of the total calorific value of the fuel utilized is, as a rule, reduced materially, with ordinary apparatus and management. It is true that the calorific value of many coals reduces as the percentage of volatile matter is increased; but this is not always the case, particularly with the coals of this country. The percentage of efficiency is, however, in general decreased with the increase of volatile matter above the limits mentioned.

Most of the coals used on the seaboard and in the eastern part of the United States have less than 20 per cent. volatile matter in their composition, and, in a general sense, with conditions favorable to each, give substantially like evaporative results. Each, however, has peculiarities of its own, so that, with ordinary apparatus and management, the results vary somewhat, and the mechanical structure of the coal seems to have more influence on the result than the chemical composition. The practical results for the softer coals of the same class, substantially alike in appearance and composition, also vary in much the same way; but in general all show a falling off in evaporative efficiency when the volatile matter is greater than 20 per cent.

The above will serve to give a general impression of the information available on the subject. The explanations that have been made of various observed phenomena are more or less conflicting because based on experiments limited in number, or carried out in a manner which did not develop all the conditions. One difficult question to explain has been the variations in practical result shown by coals of substantially the same chemical composition. These differences have frequently been referred to a less percentage of refuse, and to differences in the refuse as respects the formation of clinkers, etc., whereby less labor was required to handle the fires, the fire-doors were opened less, and there was less heat carried away in the refuse itself. All these practical questions are of importance; but it is probable that the more important variations in result are due to the different way in which the components are united chemically, and, as stated, to a difference in mechanical structure of the coal. It is known that a difference even in the allotropic form of the element affects the calorific value, Berthelot finding nearly 5 per cent. difference in calorific value due to the combustion of carbon in the form of a diamond, and of amorphous wood charcoal (*k* 101).* It is known that comparing coals of very similar composition, some will smut the hands and others will not; some have little cohesion, like rotten wood, others are like stone. The suggestion that the calorific value may vary with the mechanical structure is, therefore, very prob-

*See list of references.

able. It has occurred to the writer that these differences may be very much akin to those resulting from the mixtures and combinations of carbon and iron, resulting in cast iron, malleable iron, soft and hardened steel, etc.

In burning coal with a large proportion of volatile matter, there results a combined combustion and wasteful distillation of the volatile products, which latter are not consumed in ordinary furnaces, but escape to the chimney. The experiments show, as stated, that the loss of heat increases with the proportion of volatile products, and Rankine (*a* 292) gives the carbon value of losses on the several assumptions: First, that hydrogen only is wasted; second, that the carbon is combined with hydrogen in the same proportion as in "marsh gas" and the product wasted; and third, that the combination is in the same proportion as in "olefiant gas" and the product wasted. This would seem to imply that, at the temperature of the furnace, carbon and hydrogen unite to form hydro-carbons, but this is probably not the case. Any hydro-carbons that appear are doubtless condensed and combined as a part of the coal itself, released as gases by the heat of the furnace, and in the main carried away, wasting the heat due to their chemical composition, which it is interesting to note is less than the sum of the calorific values of the elements. The imperfect combustion resulting from driving off the volatile matter can, in part at least, be explained by the great volumes of gases disengaged, which prevent a proper admixture with the air supplied, and which, moreover, absorb a portion of the heat of the combustible consumed.

The author discusses the results of a large number of experiments, made in both Europe and America, as to the analyses, the heat value and evaporative power of coals. He quotes from Mr. Kent as follows:

"The comparison of the industrial or steaming power by Johnson's and Gruner's tests with the heating value as determined by a calorimeter, strongly emphasizes the fact that in the burning of highly bituminous coals under ordinary steam boilers, a greater percentage of heat is lost than in the burning of anthracite and semi-bituminous coals. There is but little difference in the calorimetric heating power of coals containing respectively 70 and 85 per cent. of fixed carbon; but in industrial practice the latter gives from 15 to 20 per cent. higher results. This is simply due to the great difficulty in ordinary boiler furnaces of burning the excess of volatile combustible matter which passes out of the chimney in smoke and unburned gases.

"It is greatly to be desired that tests similar to those made by Scheurer-Kestner, Mahler, and others, on European coals, should be made on the coals of the United States. The calorimetric apparatus used by Mahler is all that can be desired for determining total heating value. If our western coals which are now being wasted in steam boiler furnaces to the extent of many million dollars per year could be tested calorimetrically by this apparatus, and the results compared with those of actual boiler tests, we should then realize the enormous extent of the waste that is taking place, and inventors

would be encouraged to devise improved boiler furnaces by the use of which a large percentage of the coal now wasted might be saved."

The author, continuing, says: "A new comparison should enable us to compare the results of a test of a particular boiler, using a particular coal having certain characteristics, with those from another boiler using a different coal—either directly or by comparing the results of each with some standard. Let us try and find such a standard. If we compare directly by the efficiency, or the percentage of the total calorific value of the fuel utilized in a particular case, we find that this percentage varies with different coals."

The general conclusion to be derived from the study of the numerous experiments with coals varying considerably in the percentage of volatile matter seems to be that, while the average results of evaporative tests with a number of coals from a given region may indicate an approximate general law, the individual experiments vary so much among themselves, or even from the average, that they cannot be accurately compared with each other directly or by any fixed law of progression, and this will be particularly the case when a highly bituminous coal is used in one case and an anthracite or semi-bituminous in the other. These limitations are particularly emphasized by the fact that the results of the tests presented can only be compared with those made with customary apparatus and customary management. Mr. Kent points out that much better results have been obtained in practice with Western coals than those given by Johnson, though he found that the foreign and American tests corresponded well with each other. In order to test the relative efficiencies of different boilers in different locations, using different coals under different conditions, it would be necessary to ascertain the value of the improved furnace and of the improved care exercised in making a particular test in addition to such information as was available about the theoretical and practical calorific value of the coals employed. Even then no accurate comparisons could be made unless the practical evaporative efficiency under standard conditions of the coal used have been previously determined; and in determining the relative value of the coals still another difficulty is encountered, to wit, the variations in the efficiencies of the boilers themselves. The efficiency of the boiler is usually the very question to be settled in a boiler test; but to ascertain the comparative calorific value of different fuels, in order to use them in standard tests, allowance must be made for the difference in efficiency if different boilers are used or if the rate of combustion is varied.

The falling off in evaporative efficiency of bituminous coals, and indeed the low results with other coals, has been attributed by various writers, on the one hand, to a deficiency in the air supply, and, in connection with experiments with chimney gases, to a surplus of air admitted. Professor Unwin, in the third James Forrest lecture before the Institution of Civil Engineers (London) (*p*), states as his opinion that the "chief loss of efficiency in the operation of the boiler is the heat carried into the chimney" and that "this depends on simple conditions of air supply." Rankine (*a* 291) makes

a somewhat similar statement, but, from information now available, it appears safe to say that such conclusion is not warranted, though, doubtless, improvements in the result can be obtained in that way. If such a simple proposition were true, we would sometimes obtain very high evaporative results from ordinary boilers with rich bituminous coals; but the best efforts seem only to bring such results up, or nearly up, to those obtained with anthracite. Mr. Kent (*j* 507) hints that hot gas and air, or the conditions obtaining with a regenerative furnace, are necessary.

With the expectation that mere regulation of the air supply would secure great economy of fuel, there has been invented abroad an instrument called the "dasymeter" to indicate the percentage of carbonic acid in the products of combustion, compared with pure air. The indication depends on the weight of a vessel through which gases are being continually drawn from the chimney of a steam boiler. It is stated that with practice the stoker "learns what alterations of the damper or fire-door or thickness of fuel on the grate are necessary, or whether a permanent alteration of grate area is desirable."* Comparative experiments of ten hours' duration were made with a boiler having sixteen square feet of grate surface and 1,076 square feet of heating surface, with the following results:

Coal per 1,000 pounds of steam.	Percentage CO_2 by dasymeter.	Chimney loss.
152.6	6.8	33
125	13.1	13

At first blush these results seem to show the great value of the dasymeter, and indeed, a distinguished gentleman abroad has allowed himself to speak in enthusiastic terms of a device which will enable the percentage of carbonic acid to be continually read off "as readily as the steam pressure on a gauge," but it is the office of the engineer to look at the facts presented in a critical way. It seems suspicious to have the evaporation stated in terms of coal per 1,000 pounds of water, and by taking the reciprocal so that the results appear in the customary way, we find that the boiler only evaporated 6.55 pounds of water per pound of coal without the dasymeter, and 8 pounds with it. The first result is altogether too low for any conditions, those actually obtaining not being mentioned, whereas the second result is about what should be expected under ordinary conditions; thus raising the suspicion that the trials were made in the interests of the inventor of the particular dasymeter, but once published reached the eye of one always on the lookout for improvements, who kindly attributed to others the same honesty of purpose as himself without thinking of conditions which unavoidably enter into commercial transactions.

The above incident should not be considered as evidence that no benefit can be obtained from a knowledge of the proportion of carbonic acid in the products of combustion. An instrument of the kind might, in some cases, be very valuable as a substitute for the

*See page 99, this journal.

skilled observation of a good fireman. It is understood that manufacturers of instruments of this kind have so impressed their value on steam users that a premium is offered to firemen who will show the highest per cent of carbonic acid. From what has been said, however, in the preceding pages, it will be seen that the greatest losses occur from the fact that only the carbon in the coal is fairly well consumed, and the hydrogen, though of a higher calorific value, has little or no influence on the result. It is believed that this is a condition of things which needs further investigation with the view of improvement.

It is a maxim in making tests of all kinds to arrange all the conditions alike except the particular one to be examined. In applying this principle to the matter in hand it becomes evident, in view of the varying results obtained with coals of similar composition, that if the comparative evaporative efficiencies of different boilers are to be tested with superlative accuracy it should be with the same variety of coal burned in furnaces of like construction under standard conditions. The value of improvements in furnaces should not only be tried with the same coal, but with the same or exactly similar boilers. Tests of the efficiency of different coals offer more difficulty, as furnaces of a particular form and boilers of particular proportions are not strictly adapted for obtaining the best results from all varieties. It would seem, therefore, necessary in comparing different coals to make changes of detail suited to each, but the same rate of evaporation per square foot of heating surface should be maintained. If other than ordinary details or boilers of unusual proportions are used, the experiments made with the same would not be strictly comparable with tests made of the same coal with different details or in boilers of different proportions, and this of itself is sufficient to prevent in general any accurate comparison of boiler tests made with different kinds of coal in different parts of the country.

The difficulties in comparing the results of tests with steam boilers are very much reduced if such tests are made with the better grades of anthracite or semi-bituminous coals ordinarily sold in the market, as the difference in results between the same is, as shown by the elaborate Isherwood experiments, very small. As clearly pointed out, the practical evaporations are not accurately proportioned to the calorific values shown by calorimeter or chemical composition, but they can be compared with a fair degree of accuracy by stating the results in units of evaporation per pound of combustible. It does not appear, everything considered, that for tests of different boilers with different coals of the same general character any other plan will give results any more accurate. There will be some variations in particular samples of the different coals, even of the better grades, which will affect the results for comparison with other boilers tested with different samples; but these minor differences can only be eliminated by the adoption of the suggestion that in all standard tests of boilers, where great accuracy is required, a particular kind of fuel be employed, which, from the experience of

engineers in general, is quite uniform in quality, as regularly delivered in the market. A modification of this would be to compare the boilers in a given location by their relative performances with a fair sample of a particular fuel available in that particular locality, when a careful comparison of the standard fuel adopted in one section with that employed in another would enable the performances of all boilers in different sections to be compared.

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p. The Third James Forrest Lecture by Prof. Unwin on "The Experimental Study of Heat Engines," Minutes Inst. C. E., CXXII., 161.

ACETYLENE; A NEW ILLUMINANT.

By M. Hempel.

(*Gesundheits-Ingenieur, 1895, p. 159.*)

(*Abstract by G. R. R., Proc. Inst. C. E., Vol. CXXII, p. 445.*)

Common coal gas is well known to be a mixture of gases differing greatly in their nature and properties. The component gases have been divided into three groups in accordance with their influences upon the illuminating power of the mixture.

1. The light-giving constituents, mostly the heavy carburetted hydrogens, which have specific gravities approaching that of the atmosphere.

2. The diluents, among which are marsh-gas, hydrogen and carbonic oxide, which burn and are productive of a high temperature, but which do not possess illuminating properties.

3. The adulterants, which include chiefly the nitrogen and carbonic acid as non-combustible elements, and the ammonia, sulphur and cyanogen compounds.

These properties of the constituents of common coal gas are so

well understood that various means are adopted to eliminate the impurities or to enrich gases of low illuminating power by the introduction of heavy carburetted hydrogen gases. If it becomes possible to produce a gas consisting wholly of the constituents included under the first of these groups, an almost ideal product for illuminating purposes is obtained. Such a gas is acetylene, which has the formula $C_2 H_2$ and the specific gravity 0.91. The author describes the process of Willson* for the manufacture of calcium carbide on a large scale, and explains the use of this substance for the preparation of acetylene. He also mentions a special apparatus in which the mixture of the calcium carbide with water, with a view to the use of the resultant gas as an illuminant, can conveniently be carried on. This consists of a cylindrical vessel furnished with a perforated tray to contain the lumps of calcium carbide. A second vessel, placed at a higher level communicating with the gas producer by means of a pipe, furnishes the water supply. The gas producer is fitted with a delivery tube, a water level indicator, a pressure-gauge and an orifice for the introduction of the calcium carbide. On turning the tap of the water supply the water rises in the gas producer until it reaches the level of the tray of carbide and a rapid evolution of the gas ensues. The gas is so pure that it may at once be passed into the gas-holder for use. Any particles of sulphur derived from the coal combine with the lime of the calcium carbide and are retained in the gas producer. As soon as the tap on the gas delivery tube is closed the pressure of the gas in the producer forces back the water until it sinks below the level of the tray and the formation of the gas ceases. The plant for the manufacture of acetylene is thus extremely simple and can be contained in very small compass. Numerous tables follow setting forth the illuminating value, the comparative heat and the most effective combinations of acetylene with other gases.

THE DEVELOPMENT OF THE EXPERIMENTAL STUDY OF HEAT ENGINES.

The "James Forrest" Lecture by Prof. W. C. Unwin.
(*Abstracts from Proc. Inst. C. E., London, Vol. CXXII.*)

The author gives numerous quotations from mechanical authorities "to show that the scientific advance and practical improvement of the steam-engine were not unconnected. The improvement is mainly due to an incessant attempt to diminish the waste of fuel."

Historical data as to the Cornish engine, the early development of rotative engines, boiler, coal and engine tests are given. The author, in speaking of boilers, says: "Engineers have been too much under the impression that the evaporation depended chiefly on the type or proportions of the boiler, or the arrangement of the heating surface. But there are no obscure or complicated actions concerned in generating steam. Boilers of all types give nearly the

* Minutes Proc. Inst. C. E., Vol. CXXI., p. 372.

same results, provided only proper conditions of combustion are secured. They may differ in cost, in durability, in convenience, but in efficiency they differ less than, I think, is commonly assumed. The following table shows that boilers of extremely different types, with very different proportions of heating surface and very different rates of combustion, and even with different coals, have all reached evaporations of from 11 to 13 pounds of water from and at 212° per pound of coal:

"Variations of chimney waste are large enough to swamp all differences due to type of boiler or quality of fuel. Some experiments fail to be conclusive from the want of a scientific perception of the importance of determining accurately for each fuel the minimum necessary air-supply, and for each trial the proportion of heat lost in the chimney.

Date.	Coal burned per hour.	Cubic feet of air at 0° and 0.76 m. per lb. of coal.	Lbs. of water evaporated per lb. of coal.
February to March, 1859.	330 lbs........	206	5.86
		204	5.85
		165	6.30
		139	6.60
		120	6.66

"The earliest boiler trials carried out in a completely satisfactory way were those made by the Société Industrielle of Mulhausen, in 1859. The society offered a prize to the maker of any boiler which would evaporate 1,800 pounds per hour at 75 pounds per square inch pressure, and which would evaporate 9.1 pounds of water from and at 212° per pound of Alsatian coal of not very good quality. In those trials the calorific value of the coal was determined, the ashes were weighed and analyzed, the amount of air passing through the furnace was determined, the heat loss in the chimney measured, and a fairly satisfactory attempt was made to ascertain the dryness of the steam. With these data a proper balance sheet of the expenditure of heat could be drawn up. The efficiency of the three competitive boilers, when worked in the way shown to be best for each in preliminary tests, was practically identical and equal to about 70 per cent. With the coal used in these trials 130 cubic feet of air per pound of coal are chemically necessary for complete combustion. It was found that the reduction of the air supply almost to this limit, and to a point at which there was definitely incomplete combustion, reduced the chimney waste and increased the efficiency of the boiler. In two special trials, each of a week's duration, the evaporation was 9 pounds, with 331 cubic feet of air per pound, and 9.53, or 6 per cent more with 247 cubic feet.

"Some striking results, showing the dependence of boiler efficiency on air supply, were obtained by members of the same Alsatian Society at the works of Dollfus, Mieg & Cie. From several series of trials the following is selected:

Type.	Ratio of Grate to heating surface.	Coal per square foot of grate per hour.	Evaporation from and at 212° per lb. of coal.	Coal.
Cornish........	....	7.2	11.9	Welsh.
Lancashire....	1 : 36	22.9	11.2	Lancashire.
Galloway......	1 : 24	8.5	11.6	Anthracite.
Portable	1 : 69	12.8	11.8	Welsh.
Tubular.... ..	1 : 46	10.8	11.9	Anthracite.
Babcock.......	1 : 38	8.9	11.8	"
Marine........	1 : 34	22.4	12.9	Welsh.
"	1 : 50	25.5	12.5	Lancashire.
Thornycroft...	1 : 70	7.7	13.4	Welsh.
" ...	1 : 61	18.6	12.5	"

"Here the efficicncy increases as the air supply is diminished, even when it approaches the minimum chemically necessary. There are two ways in which decrease of air supply tends to increase efficiency. The quantity of heated air reaching the chimney is less, and the velocity of the heated gases in the boiler flues is less, so that there is more time for heat absorption.

"The determination of the air supply to a boiler is not altogether an easy operation. An anemometer was used in Alsace, and in suitable conditions it will give approximately accurate results. In recent trials chemical analyses of samples of the furnace gases have been made, and the amount of air supplied calculated from the percentage of CO_2. This method is accurate in principle, but the

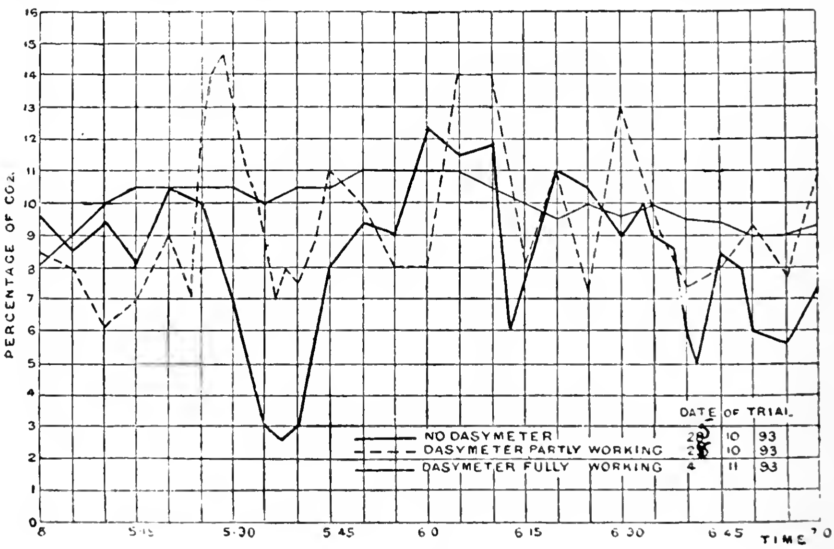

FIG. 45.

samples analyzed are a very minute fraction of the total chimney discharge, and the samples may not be average samples. Neither anemometer nor chemical analysis is suited to serve as a means of the regulating the air supply in the ordinary working of a boiler. What is wanted is an instrument as easily read as a pressure-gauge and giving continuous indications.

"The Dasymeter,* invented by Messrs. Siegert & Dürr, of

*Illustrated and described in original.

Munich, requires initially exceedingly delicate adjustment, and its indications must be checked from time to time by a Bunte's burette. It is set to read zero with pure air, and then any increase in density due to CO_2 is read as a percentage on the scale. When in adjustment it is as easy to read the percentage of CO_2 in the furnace gases as to read the pressure on a pressure-gauge. When the dasymeter is fitted to a boiler, the stoker has directions to adjust the supply of air so that the furnace gases have about 12 per cent of CO_2. After a little time the percentage of CO_2 can be kept very constant.

"The diagram shows records taken on three days at a boiler provided with a dasymeter. The dasymeter is now largely used for boiler furnaces in Germany, and the author is assured that in many cases a saving of 20 per cent of the fuel has been secured.

"The following results were obtained in two trials of a boiler 1,076 square feet heating surface and 16 square feet of grate surface, the same coal and feed at the same temperature being used on both days. On one day there was a low dasymeter, and on the other day a high dasymeter, reading:

No. of Trial.	Duration, Hours.	Coal per 1,000 lbs. of Steam.	Water per Hour per Square Foot of Heating Surfa e, lbs.	Steam Pressure, Atmospheres.	Per Cent. of CO_2 by Dasymeter	Chimney Loss, Per Cent.
1	10	152.6	2.03	5.88	6.8	33
2	10	125.0	2.39	7.28	13.1	13

"The air supply is the one controllable factor in the working of a boiler furnace, and we have trusted far too long to the practical experience of boiler makers and the common sense of stokers to regulate this important factor in boiler management. We do not trust the common sense of the stoker to regulate the boiler pressure or the water-level, and is equally necessary, if economy is to be obtained, that he should be supplied with some means of ascertaining definitely whether his management of the fire is good or bad. The author believes that in good and large installations, at least, it will come to be considered as necessary to have an instrument of the dasymeter type as to have a pressure-gauge, and this may be regarded as a gift of science to the practical engineer."

The author refers to and quotes from numerous experiments and publications, and points out the effect they have had upon the development of heat engines. In speaking of the experiments of Hirn,* an Alsatian engineer, the author calls attention to "the fact that the admirable series of engine tests, the first tests in England in which the heat quantities were accurately measured, which were made by Mr. Mair Rumley and published in 1882, 1885 and 1886, were carried out strictly in accordance with Hirn's methods.

"Hirn's heat measurements in the engine trials of 1854-6 showed

* "Memoire sur l'Utilité des Enveloppes à Vapeur," Bulletin de la Société Industrielle de Mulhouse, 1856; "Memoire sur la Théorie de la Surchauffe dans les Machines à Vapeur," Bulletin, 1857.

the important and even unaccountably large influence of the steam jacket on the steam consumption. Its effects could not in any way be explained as merely the arrest of external radiation, for the decrease of heat losses in the engine proved to be larger than the heat yielded to the cylinder by the jacket. It was in studying the action of the jacket that Hirn came to perceive and, before anyone else, to directly measure the initial condensation of steam in the cylinder.

"The following are some results obtained a few years later by Hirn and Hallauer on a Corliss engine: Working without a jacket, the initial condensation was 62.3 per cent. The proportion of water in the steam at release was 41.4 per cent, so that 20.9 per cent at least was re-evaporated during expansion. Working with a jacket, the initial condensation was 46.5 per cent, or 16 per cent less than in the unjacketed trial. Further, the proportion of water present at release was only 15.3 per cent, so that 31.2 per cent had been evaporated during expansion. Hence, the gain from the jacket in those cases where it produces a considerable effect arises in two ways. The prejudicial initial condensation is considerably diminished, and more heat is given back from the cylinder wall during expansion when the temperature in the cylinder is higher and when it is partially used in doing work, and less during exhaust when the temperature is lower and it does no useful work.

"The magnitude of the condensation increases with the range of temperature to which the cylinder wall is subjected. It is larger in condensing than in non-condensing engines and larger with high ratios of expansion. It is only in the last ten years that the magnitude of the loss due to cylinder condensation has been at all generally understood.

"Some time ago the author ventured to say that there was no trustworthy engine test which showed that the consumption of steam with a jacket is greater than without a jacket. He believes that is still true, but undoubtedly the economy due to the jacket varies in different cases from 30 per cent to nearly zero. Roughly, the jacket is more useful with small engines than with large; with slow engines than with fast engines; but all this amounts to little more than saying that the jacket is most useful in those cases where the initial condensation is largest. Just in proportion as the engine, whatever its type, is of the highest class and most scientific design, the jacket is less useful. No one probably designed better simple engines than Corliss, and Corliss did not use jackets. In an experiment by Delafond on a large Corliss engine at Creusot, the jacket effected an economy of only 2 per cent. The same rule holds with compound engines. Hirn found an economy of 25 per cent due to the jackets in a Woolf engine, tested in 1855, but since then the compound engine has been improved, and the advantage of the jacket is less. Professor Witz made very accurate experiments with a large compound engine of about 600 I. H. P., provided with jackets both to cylinders and receiver. The trials were strictly comparable, the pressures, temperature ranges, and total power developed being nearly the same. The total condensation in the jackets was 12 per

cent of the steam used, so that the jackets were not inactive. Yet the absolute saving of steam due to the jackets was only 4 per cent, or, allowing for the heat saved by returning the jacket drainage to the boilers, 6.6 per cent.

"It is perhaps probable that as the temperature range in the cylinder is diminished by compounding, the temperature gradient from the jacket to the interior of the cylinder is diminished, and the rate of transmission of heat decreased. It appears, then, that as engines are better designed the jacket is of less use, and it is not by means of the jacket that the waste due to cylinder condensation can be got rid of, or the highest economy of the steam engine reached.

"The jacket reduces, but does not prevent, initial condensation. Hirn looked for some more powerful way of heating the cylinder wall without causing condensation; he found it in superheating. He constructed, in 1855, a superheating apparatus in the flues of the boiler Logelbach, which still exists. The experiments with superheated steam were carried out between 1855 and 1856, and showed clearly the effectiveness of the method in reducing condensation. Superheating came largely into use in the years 1860-70, in England, in marine engineering practice, having been introduced here by John Penn. In every case in which it was used an economy of coal was realized. Generally the economy amounted to from 15 per cent to 20 per cent. It was ascertained that this was due strictly to economy of steam, and not to the utilization of heat in the boiler previously wasted. But the use of superheated steam in this country was gradually abandoned, partly, no doubt, because practical engineers had no clear idea why superheating should produce so large an economy, and they were not indisposed to abandon a complication the action of which they could not satisfactorily explain to themselves.

"In Alsace superheating has never been entirely abandoned, and during the last ten years hundreds of boilers have been supplied with superheaters. So far as the author can ascertain, no difficulty arises in using steam superheated to 500° F., and in good and large engines the steam consumption is reduced, when the superheating amounts to 100°, by 15 per cent on the average. The author has no doubt that superheating will be largely used again. The practical difficulties exist, but they are not insuperable.

"No possible improvement of the steam engine, of which we have any knowledge at this moment, offers anything like so great a chance of important economy as the re-introduction of superheating, and especially of superheating to at least 100° or more above the saturation temperature of the steam. The author obtained in Alsace, on a very good 500 H. P. compound mill engine, with jackets and every appliance for economical working, an economy of 15 per cent. Mr. Mair Rumley has fitted a superheater to a Babcock boiler supplying a triple engine, and has obtained an economy of 10 per cent. Mr. Willans made four experiments on a simple condensing engine with saturated steam and four corresponding experiments with superheated steam. The mean amount of superheating was only 35° F.;

but a mean economy of 8 per cent of steam was obtained in the superheating trials. In these cases the economy is economy of steam, and therefore is not due to any increase of boiler surface or increase of efficiency in generating the steam. Lately Prof. Schröt-ter, of Munich, has been experimenting with a small special compound condensing engine of only 60 I. H. P., running at the moderate piston speed of 380 feet per minute, and with the not excessive boiler pressure of 165 pounds per square inch. The H P. cylinder is not jacketed. The L P. is jacketed, with receiver steam. In this case, in a tube superheater of rather special construction in the uptake of the boiler, the steam is superheated to 670° F., or nearly 300° above the saturation temperature corresponding to the pressure. In two trials of six and eight hours' duration, periods quite long enough for accurate determination of results with so accomplished an observer as Prof. Schrötter, the consumption of steam was only 10.2 pounds per I. H. P. hour, and the consumption of German coal of moderate quality only $1\frac{1}{4}$ pounds per I. H. P. hour. The steam consumption is the lowest on record for any engine, of any type or size, and is very remarkable for so small an engine.

"It is often argued that as very little heat is required to superheat steam it cannot produce much effect. The answer is, that a small amount of heat rightly applied in preventing initial condensation produces a disproportionately large effect. That is consistent with the strictest principles of thermodynamics. In the Schmitt engine only 8 per cent of the heat was used in superheating the steam, and to this 8 per cent the remarkable economy is due. In a steam jacket acting well about 12 per cent of the steam used is condensed, and to this 12 per cent is due the advantage of the jacket which often reduces the amount of steam used in the cylinder by 20 per cent to 30 per cent. But the heat from a jacket is much less efficiently applied than the heat taken direct to the interior of the cylinder by superheated steam and used primarily in maintaining the temperature of the admission surface. Further, the quantity of superheat brought into the cylinder in a given time increases with the speed of the engine, while jacket heat diminishes in effect as the speed is greater. The action of the superheated steam is shown clearly enough on the indicator diagrams. In the author's trials in Alsace the wetness of the steam in cut-off in the H. P. cylinder with jacket, but without superheating, was 35 per cent; with steam superheated 100° it was only 15 per cent. In the trial with the Schmitt engine there was no moisture at cut-off in the H. P. cylinder, and the steam remained dry nearly to the end of the stroke."

The author, in referring to the two series of experiments of the late P. W. Willans,* says: "There is a series of non-condensing and a series of condensing trials; in each there are trials of simple, compound, and triple engines; and for each of these, again, trials with initial pressure varied, with expansion varied, and with speed

* Willans' "Economy Trials of a Non-condensing Steam Engine," Proc Inst. C. E., Vols. XCIII. and XCVI.; "Steam Engine Trials," Proc. Inst. C. E., Vol. CXIV.

varied. The results, tabulated in the clearest way, form a quarry of scientific data, but at present in the main an unworked quarry.

"The purely dynamical actions in the engine, like the thermal actions, have proved too complex for any purely rational treatment. Here, also, it is necessary to check the results of theory step by step by reference to experiment. The total friction of engines has been determined by various methods and proves to be more nearly independent of the load than the earlier writers assumed. Hirn converted the beam of his engine into a flexion dynamometer which drew a diagram of the effective work of the engine, and some method of this kind might be revived with much advantage. Prof. Carpenter and Mr. Preston have attempted experiment on the friction of different parts of the engine, with the striking result that the crank-shaft bearings absorb nearly half the frictional work of the engine and the piston about one-fourth. Mr. Ransom has studied experimentally the action of governors, and, lastly, Prof. Dwelshauvers Dery has attempted a general experimental study of all the dynamical actions which affect the motion of the engine.*

"Since 1845 purely scientific men, scientific experimenters, and practical engineers, have all been engaged in the study of the steam engine. The author does not believe that any of the three can claim all the credit for the improvement of the steam engine to the exclusion of either of the others.

"What has been achieved is shown in the following table:

RECENT ENGINE TESTS—LOWEST STEAM CONSUMPTION.

KIND OF ENGINE.	I. HP.	Boiler Pressure. Lbs. per square inch.	Piston speed. Feet per minute.	Steam per I. HP.-hour. Lbs.
Simple—				
Sulzer	284	87	372	18.4
Corliss	137	62	....	17.5
Compound—				
Dujardin	548	90	570	13.46
Sulzer	247	85	493	13.35
Wheelock	590	160	612	12.84
Leavitt	643	135	371	12.16
Bollinckx	305	91	479	12.19

"In popular writings nothing is commoner than to find the efficiency of electric machinery and of steam machinery contrasted, to the great discredit of the latter. The dynamo, it is said, has an efficiency of 90 per cent to 95 per cent; the steam engine an efficiency of only 10 per cent. What a barbarous machine, after all the labor of a century, the steam engine must be! The comparison is generally made by an electrical engineer, and the first reflection which occurs to one is that, of all people, the electrical engineer should be the last to abuse the steam engine. Without the steam engine the dynamo would be a useless mass of metal and wire. But, passing

* "Etude Expérimentale Dynamique de la Machine à Vapeur." Paris, 1894.

over the moral aspect of the question, the ingratitude of the electrical engineer, the comparison is an unfair one, and shows a want of apprehension of that important law of the motivity of heat, which is one of the two fundamental laws of thermodynamics. Heat-energy is undirected or mob energy. It lies in the nature of the terrestrial conditions in which use has to be made of it, that only a fraction is convertible into directed or mechanical energy. The task of the steam engine is to do its best with the fraction which is convertible, and in that point of view is not an inefficient machine. The dynamo has a much easier task. Energy is supplied to it in its directed or wholly convertible form, and naturally, in transforming one kind of directed energy into another kind of directed energy, only a small fraction need be wasted." C. E. B.

THE LAVAL STEAM TURBINE.

By E. J. Brunswick.

L'Electricien, Vol. IX, p. 115.

(*Abstract by R. W. W. Proc. Inst. C. E., Vol. CXXII, p. 461.*)

The Author, in an article on a portable search-light apparatus, describes the Laval turbine as the lightest steam generator that can be employed for military field purposes where small weight is of great importance. The Author considers that the Brotherhood engines and the Parsons steam turbines, which have hitherto been used for this purpose, do not meet all the requirements of the case, i. e., light weights to facilitate transport and at the same time good efficiency. He describes the principle of the Laval steam turbine as similar to that of the Pelton water-wheel. Instead of the power being obtained from steam expanding against a piston in a close cylinder, the kinetic energy of the steam after escape from an orifice is utilized. The steam impinges on the vanes of a wheel revolving at the exceedingly high velocity of 25,000 to 30,000 revolutions per minute. With careful geometrical design a theoretic efficiency of 87 per cent is easily obtained, while in practice the commercial efficiency is stated to vary from 45 per cent, in the small sizes, up to as high as 60 per cent in the larger turbines.

The turbines consist of two essential parts, the wheel and the casting containing the steam passages and escape orifices. These are so designed that, although the steam enters them at the pressure of the boiler, by the time it reaches the exit opening adjoining the wheel the pressure is only that of the atmosphere. In fact, the potential energy of the steam has been all converted into kinetic energy, in the same way as in many hydraulic turbines.

As the velocity of the steam on leaving the orifices is excessively high, 2,560 feet per second for 85 pounds' pressure, the actual period of contact between it and the revolving vanes is exceedingly small. It follows that where the circumferential dimensions of the disk and the size of the diverting orifices permit, it is possible to augment the power of the turbine by increasing the number of vanes. Owing to this, the consumption of steam per H. P. remains practically con-

stant at all loads as the variation of power is effected by regulating the number of escape orifices in use. The consumption of steam for turbines of 5, 10 and 15 B. H. P. is stated to be about forty-four pounds per H. P., with atmospheric exhaust, and with a boiler pressure of 85 pounds.

The Author then proceeds to describe the essential mechanical details of construction. At the excessively high speeds of these turbines, i. e., 30,000 revolutions per minute for the 5 H. P. size, and 24,000 revolutions for the 10 and 15 H. P., the centrifugal forces are enormous. The inventor has shown great ingenuity in overcoming slight want of balance by certain gyrostatic propensities of the revolving parts. The speed of the principal axis is reduced in the ratio of 10 to 1 by screw-gearing, and hence the dynamos need only be constructed for more moderate speed of 2,400 to 3,000 revolutions. The weights of the turbines, complete, are as follows:

Effective Power of Turbine. H P.	Speed of Turbine. Revolutions per min.	Speed of Dynamos. Revolutions per min.	Weight of Turbine only Lbs.
5	30,000	3,000	286
10	24.000	2,400	440
15	24.000	2.400	517

TESTS OF A TEN HORSE-POWER DE LAVAL STEAM TURBINE.

By William F. M. Goss, M. A. S. M. E.

(*Abstract, Trans. Am. Soc. M. E. Vol. XVII.*)

1. Description of the Engine.

In the de Laval steam turbine, jets of steam, delivered from suitable nozzles, are made to impinge against the buckets of a light turbine wheel. The steam enters the buckets from one side of the wheel, and passing through, is discharged or "exhausted" from the opposite side. The motion of the turbine shaft, which, under the action of the jets, is extremely rapid, is communicated by gearing to a heavier and slower-moving driving shaft carrying a fly-wheel of small diameter; from this wheel the power of the engine is delivered. Regulation of speed is secured by means of a throttling governor, which controls the pressure of the steam admitted to the nozzles.

The turbine wheel is built up of sixty-three steel segments, each carrying a bucket and a portion of the light outside rim. The segments are held in place by means of suitable collars, which grip them on either side. The wheel is mounted upon a long, slender shaft, having sufficient flexibility to allow the system at speed to revolve about its center of gravity, even though this may not agree with the geometrical axis of the shaft. The gear upon the turbine shaft is of steel, solid with the shaft; that upon the drive shaft has its teeth formed in a bronze ring, which is carried by a solid iron center. The smaller gear has twenty-one teeth, the larger one 208 teeth, giving a ratio of 1 to 9.90476.

The nozzles which serve to deliver steam to the wheel are four in number, and are so fixed in the frame of the engine as to act upon the turbine wheel at points which are equally distant from each other. Two of the four are provided with stop-cocks, which, when closed, put out of action the nozzles with which they are connected. By means of the stop-cocks, therefore, the engine may be run under the action of two, three, or four nozzles, at the will of the engineer.

The distinguishing feature of the engine, perhaps, is to be found in the form of the nozzles. All are diverging, the throat or smallest diameter being approximately 2 inches from the discharge end. Three have a diameter in the throat of 0.138 inch, and one a diameter of 0.157 inch.

It is assumed that the form of the nozzles is such that the pressure of the steam as it passes from the orifice will be that of the surrounding medium, and, since the flow is nearly adiabatic, it is clear that if this condition is realized all the energy of pressure is transformed into energy of motion before the steam is allowed to impinge upon the buckets of the turbine wheel. The medium surrounding the nozzles in the machine is practically that of the exhaust, so that the expansion from the pressure of the boiler to that of the exhaust is complete before the steam has contact with any moving part of the machine.

Lateral motion of the driving shaft is limited by contact between the large gear and the bearings on either side. With this shaft fixed, the double spiral of the gears makes lateral motion of the turbine shaft impossible. All forces, therefore, tending to displace the turbine wheel laterally are transferred to the slow-moving shaft, where ample rubbing surfaces can be provided without seriously impairing the efficiency of the machine through frictional losses—a happy solution of an otherwise difficult problem. Viewed as a piece of mechanism, the engine tested appears to merit high commendation, both as to design and workmanship, but the service which has thus far been obtained from it is not sufficient to show the effect of long-continued use.

II. The Tests.

Arrangements for Testing.—The power of the engine was absorbed by a Prony brake, cooled by constant streams of water. The exhaust steam was piped to a Wheeler condenser, open to the atmosphere. The water resulting from condensation was drained into tin buckets, which were changed and weighed at regular intervals.

Gauges were used to show the steam pressure both above and below the governor throttle, the former giving the pressure available at the engine, and the latter the pressure under which, in consequence of the action of the governor, the steam was admitted to the nozzles. A manometer was also attached to the exhaust pipe, but as this pipe is large (3 inches in diameter) and the connection with the condenser close, the observed pressure was never appreciably different from that of the atmosphere.

Conditions and Results.—The boiler pressure for all efficiency

tests was 130 pounds by gauge, for which pressure the particular nozzles used were designed. The rated speed of the fly-wheel is 2,400 revolutions per minute (23,771 for turbine wheel), but this standard was not maintained for all the tests. The governor was adjusted several times as the work progressed, and it was not until several tests had been run that the proper speed was secured. It is believed, however, that the differences of speed recorded do not materially affect the value of results for purposes of comparison.

The tests are grouped into three series, the first including those for which all four nozzles were in action, the second those with three, and the third with two. The several tests in each series were intended to vary from each other only in amount of power delivered from the wheel. All tests were of thirty minutes' duration, and all observations were taken at five-minute intervals. The conditions of each test were maintained with such uniformity that the observations of any five-minute interval were very nearly identical with the average of all observations taken for the test.

It will be seen that, with all four nozzles in action, and with the engine developing a little more than its rated power, the steam consumption per horse-power per hour is as low as 47.8 pounds. In comparing this result with results obtained from other engines, the small size of the engine tested (10 horse-power) should be kept in

TESTS OF A TEN-HORSE-POWER DE LAVAL STEAM TURBINE.

A SUMMARY OF RESULTS OF TESTS.

Nozzles.	Number of Test.	Revolutions per Minute of Belt Wheel.	Brake Horse-power.	Steam Pressures by Gauge: In Boiler.	Steam Pressures by Gauge: In Engine below Governor Valve.	Total Pounds of Steam per Hour.	Pounds of Steam per Brake Horse-power per Hour.
All four nozzles in action, three having a diameter in throat of 0.138 inch and one a diameter in throat of 0.157 inch.	1	2138	0.00	130	17.1	120.8	......
	2	2545	1.63	130	42.2	210.3	128.6
	3	2038	2.36	130	48.5	230.8	99 8
	4	2118	2.97	130	55.6	254.6	85.7
	5	1917	3.46	130	61.9	275.5	79.6
	6	2072	4.38	130	70.8	313.0	71.5
	7	2128	5.10	130	76.9	328.5	64.4
	8	2576	7.52	130	99.6	403.0	53.6
	9	2453	8.24	130	104.4	422.8	51.3
	10	2411	10.33	130	126.3	491.8	47.8
Three nozzles in action, two having a diameter in throat of 0.138 inch and one a diameter in throat of 0.157 inch.	11	2584	0.00	130	31.3	121.4	......
	12	2112	3.95	130	83.6	267.8	67.8
	13	2125	4.77	130	93.4	286.0	60.0
	14	2490	6.50	130	111.7	346 3	53.3
Two nozzles in action, each having a diameter in throat of 0.138 inch.	15	2546	0.00	130	42.2	99.3	......
	16	2049	1.95	130	83.5	162.6	83.4
	17	1909	3.43	130	121.1	222.9	65.0
	18	2412	3.87	130	127.0	229.6	59.3

mind, and also the fact that the rate of consumption stated is based upon brake power. The efficiency of the engine falls off rapidly as the load is decreased, and, as would be expected, the effect is most marked when all the nozzles are in action.

The engine requires very little attention and is almost noiseless in action. The governor is quick to act, and its speed regulation appears to be fair, except when changes of load are large and suddenly made After such a change, the engine requires a little time before settling down to steady running under the new conditions.

Starting Power.—As the speed of the de Laval engine is high, it is evident that the force in action must be comparatively low. To determine the maximum resistance under which the engine might be expected to start, the brake was clamped upon the fly-wheel so that the latter could not turn within it. Steam was then admitted to the engine, and readings were taken from the scale under the brake arm. The result of this process, of course, depends upon the steam pressure and the number of nozzles in action. With all nozzles, and with a steam pressure of about 125 pounds by gauge, the maximum starting-power is equal to a force of 30 pounds acting at a radius of 1 foot. The following tabulated data gives the starting-power for different pressures, and when two, three, or four nozzles are in action:

STARTING POWER OF ENGINE.

	Four nozzles in action.		Three nozzles in action.		Two nozzles in action.	
Steam pressure by gauge	125.2	71.1	125.2	71.1	125.2	71.1
Effective radius of brake arm, feet..	1.5	1.5	1.5	1.5	1.5	1.5
Reading of scale under brake arm, lbs	20.0	12.1	14.1	9.0	9.5	6.0
Equivalent force in pounds, acting at a radius of one foot............	30.0	18 2	21.2	13 5	14.3	9.0

DISCUSSION.

By J. W. Lieb, Jr., of New York.

It may be of interest to the members to learn that in a few weeks the Edison Electric Illuminating Company of New York will have in operation at one of their stations two 300 horse-power de Laval steam turbines with attached dynamos. These turbines were built by the Maison Breguet, Paris. They were ordered under guarantee to comply with the following specifications:

Each 300 horse-power turbine is to drive two Desroziers dynamos, each of 133 horse-power capacity. The turbine shaft is to run at 13,000 revolutions, driving at a speed of 1,300 revolutions, by means of helical gearing, two dynamo shafts situated on either side of the turbine shaft. Each dynamo is to be capable of generating continuously without undue heating 770 amperes at 130 volts or 625 amperes at 160 volts. If the turbines are built to be operated either condensing or non-condensing, as a mongrel type with a steam pressure of 142 pounds per square inch at the throttle and with a vacuum of 65 cm. at the condenser, the steam consumption per brake horse-

power is guaranteed not to exceed 18.7 pounds; with a free exhaust the steam consumption is not to exceed 35.2 pounds. If it is desired that the turbines be operated ordinarily with a condenser by changing the disk, the guaranteed steam consumption can be reduced to 16.5 pounds per brake horse-power. In this case the turbine disk would have a diameter of 29 inches instead of 19⅝ inches for the mongrel type.

GAS AND PETROLEUM ENGINES AT THE ANTWERP EXHIBITION OF 1894.

By G. Lambotte.

(*Revue Universelle des Mines, Vol. XXX, May, 1895, page 128.*)
(*Abstract by J. R. B. Proc. Inst. C. E., Vol. CXXII, p. 463.*)

The author commences this article with a brief explanation of the general theory of these engines. The gas and petroleum engines examined were exhibited by twenty-one houses, Belgium contributing fifteen, England fifteen, Germany thirty, and France six. Each pattern of engine is described in detail, and, where conspicuous, their defects and advantages pointed out. A general comparison of the various types employed is also given. The author commends the exhibits of England, where horizontal type is affected. The engines are of simple construction, solid, well balanced, and elegant, without useless wealth of detail. The German engines of large power, and especially the petroleum engines, are vertical; they affect an excessive amount of detail, to which, in a great measure, practical considerations appear to be sacrificed.

On account of the formidable competition of England and Germany it has been found necessary to construct the Belgian motors as simply as possible, while leaving nothing to be desired in their efficiency; and this, the author claims, has been successfully accomplished. The number of gas and petroleum engines employed in Belgium is very limited, and the reason for this, in a country where fuel is so cheap, appears to be the prejudice of the small manufacturer. At the beginning of 1894 there were in Belgium only 1,069 gas motors, representing 3,490 H. P., while in England at the same period the number amounted to 40,000. In France, where gas is costly, the number of engines in 1889 compared with that of Belgium, for the same population, as 2 to 3; and engines of large power have hardly been introduced into the latter country, owing to the scarcity of anthracite coal.

The petroleum motor which was barely represented at Paris in 1889, occupied a prominent place at the Antwerp exhibition; and the author holds that, considering the improvements of which the gas engine is undoubtedly capable, it seems reasonable to expect yet greater developments from the more complex and, in many respects, more advantageous petroleum engine of modern birth. A comparison is then drawn between steam, gas and petroleum motors with regard to economical and other advantages.

Based on conditions prevailing in Brussels, and taking into ac-

count interest on first cost, maintenance and working expenses, the results shown in the following table are arrived at, showing that up to 10 H. P., the petroleum motor is the most economical; that at that power the cost of all is about the same, and that above it steam is the cheapest for continuous work of any duration:

	Cost in Pence per I. H. P. per Hour.		
Power.	Gas.	Petroleum.	Steam.
2 I. H. P.	2.93	1.74	2.91
10 I. H. P.	1.06	0.97	1.06
50 I. H. P.	0.49*	....	0.49

For 50 H. P. the daily cost is the same for coke, gas and steam, but in the neighborhood of anthracite mines the advantage lies with the gas engine, which would only require 1.33 lbs. of anthracite per H. P. per hour, whilst the steam engine would consume 3.33 lbs. of coal.

The paper also contains a comparison of the power developed per pound of coal in each class of engine, taking into account the by-products realized in the manufacture of the gas, and concludes with the remark that when the gas engines shall have been perfected by improvements in the cycle and generator the solution of the problem of large power gas motors may be expected; reference being then made to the 320 H. P. engine at Pontin† which consumes 50 per cent less coal than a good steam engine of the same power.

EFFECT OF TEMPERATURE ON STRENGTH OF WROUGHT IRON AND STEEL.

By Prof. R. C. Carpenter.

(*Advance Proof, Trans. Am. Soc. M. E., December, 1895.*)

The tests were performed on an Emery Testing Machine, having a maximum capacity of 200,000 pounds.

The method employed in making the tests differed from that employed in ordinary testing, simply in the provision for heating the test-piece to a specified temperature and maintaining it at that point throughout the test. A solid block of cast iron made in two halves and held in position by clamps, was heated externally and transmitted its heat to the test-piece. The temperature was measured by a mercurial thermometer, the upper part of which was filled with nitrogen to prevent vaporization of the mercury at high temperatures; it was graduated to 900 degrees Fahr. The bulb of the thermometer was put in direct contact with the test specimen, and was partly surrounded by the solid metal of the cast-iron jacket. The length of the jacket was about 2 inches greater than the gauged length of the test specimen.

The iron jacket when in position on the test specimen was heated by a Bunsen burner having four jets.

This method of heating the test-piece proved very satisfactory,

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*Generator gas.

† Minutes of Proc. Inst. C. E., vol. cxx, p. 420.

and, as will be seen by consulting the tables and curves, gave very uniform results.

The specimens tested were turned to dimensions and those belonging to each class, wrought iron, tool steel, and machinery steel

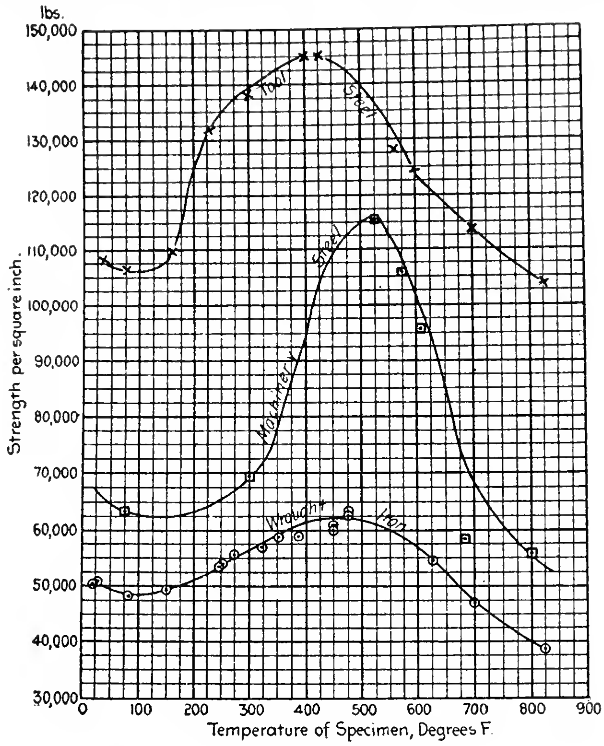

Diagram Showing the Ductility of Wrought Iron and of Tool Steel at Temperatures to 825°F.

FIG. 46.

were as nearly uniform in quality as could be obtained from the stock in Sibley College. About thirty specimens of wrought iron were tested and about twenty-five of steel, the temperatures varying in each test from 22 degrees to 825 degrees, the lowest temperature being obtained by use of a freezing mixture, the highest temperature as explained. The method of heating the specimen prevented the use of appliances for measuring extension while under stress, so that information could not be obtained regarding the elastic limit or modulus of elasticity.

Results.—The general results of the test are shown on the curves from which it will be noted that all the curves have a point of contra-flexure at about 70 degrees Fahr. and another at a temperature not far from 500 degrees. The maximum strength is found at temperatures of 400 to 550 degrees Fahr.

The elongation in 8 inches of length for the tool steel and wrought iron, is shown on the curves in figure, from which it is noted that these curves are of the same general form, and agree in showing smallest elongation when at a temperature about equal to the boiling point of water. There is considerable variation in the results given by individual specimens, especially for the tool steel; and there is,

for this reason, doubt as to the exact position and form of the curve. A large portion of the discrepancy is no doubt due to the methods which had to be employed in measuring the elongation.

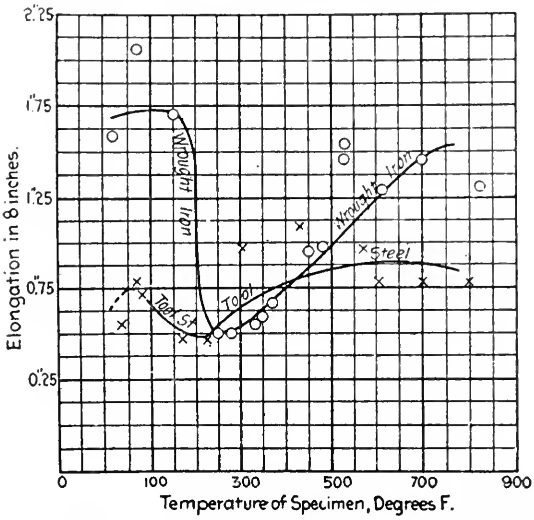

Diagram Showing the Relation Between Tensile Strength and Temperature of Iron and Steel up to 825°F

FIG. 47.

The paper is accompanied by tables giving details as to each specimen tested.

C. E. B.

THE RELIABILITY OF "THROTTLING CALORIMETERS."

By JAS. E. DENTON, HOBOKEN, N. J.

(*Abstract, Trans. Am. Soc. M. E., Vol. XVII.*)

The first investigation was undertaken to determine:*

First. Whether it is, or is not, a fact that the proportion of moisture in steam as determined by the accepted methods of using a "throttling calorimeter" may be considerably in excess of the true proportion of such moisture.

Second. The conditions under which "throttling calorimeters" should be used, or the precautions necessary in using them, in order to insure practically accurate conclusions regarding the proportion of moisture in the steam under examination.

Experiments were made under three conditions, using small "throttling calorimeters," with the entire output of steam from a 75 H. P. boiler flowing through a 3-inch pipe. Tables XXII and XXIV give records of some of these tests.

The results made it evident that, while the small "throttling calorimeter" might be relied upon to determine correctly the amount of moisture in the sample of steam and water which is drawn into the instrument from the larger volume of mixture in a steam main, the

*See also experimental data covering certain parts of the investigation; Jacobus, Trans. Am. Soc. M. E., vol. xvi., pages 448, 1017.

percentage of moisture in such a sample may largely exceed the percentage in the steam main, if the moisture in the latter separates itself from the steam so as to accumulate at the point of connection of the calorimeter. It became necessary, therefore, to determine whether, under the usual conditions of good boiler practice—that is, for conditions where the moisture does not exceed one and one-half per cent—there can be such a separation of the moisture from the steam so as to cause the erratic indication of the calorimeter.

To investigate this question two sets of experiments were made. The results of the first set confirmed the hypothesis that less than one-half per cent of moisture in a steam main might separate itself from the steam, and accumulate at the bottom of a pipe in a stream which would impinge against a calorimeter nipple in its path so as to flow up the side and into the orifice of the latter, thereby causing the indications of the instrument to greatly exaggerate the true percentage of moisture in the main. Evidently, if this hypothesis were correct, the extent to which moisture could separate itself between the outlet for steam from a boiler to the point where a calorimeter was attached would depend upon the velocity in the steam main, the diameter of the latter, and the distance from the boiler outlet to the calorimeter. In other words, the moisture, in dropping out of the steam in a horizontal pipe, would probably roughly follow the law of a falling body, and to ascertain how far this was the case a second set of experiments was made.

The results (Table XXIII) clearly indicate that, in traveling a little more than twice the distance in the three-inch main—which would be necessary in order for a body to fall by gravity through the diameter of the pipe—practically all of the moisture in the steam main would escape through the calorimeter.

CONCLUSION.

The author thinks these results afford a key for the explanation of the erratic indications of "throttling calorimeters" in practice, which all extensive users of them have met to a greater or less extent. Variations in the proportions and arrangement of nipples, in the rate of evaporation, relative location of calorimeter, and position of steam mains leading to the point of attachment of the latter, will give rise to an infinite variety of results in the degree of the error which may be involved in the use of the instrument.

All parts of the surface of any form of nozzle inserted in the steam main will act as a collector for moisture, which will adhere to the metal so as to resist being detached by the comparatively swift main current of steam, but which will allow itself to be gradually drawn into the nozzle by the gentler current of steam which flows into the calorimeter, because the latter has only to overcome the resistance to sliding of the water along the metal.

Under this view there seems to be no possible method of depending solely upon small "throttling calorimeters" to determine with certainty the percentage of moisture in a steam main. By using several instruments simultaneously, with the orifices of the nipples lo-

cated at different parts of the cross-section of the main, or by making the nipple of a single instrument movable so as to explore the interior of the pipe—an approximately correct judgment may be made regarding the average moisture, which will be sufficiently complete for commercial purposes.

By combining a single calorimeter with a separator acting on the whole current in the steam main, however, the source of error in the calorimeter may be so far eliminated as to make its indications reliable. This method is based upon the fact that, by using a separator of sufficiently large proportions to confine the velocity of flow within certain limits, the moisture in the steam leaving the separator can be reduced from any probable amount to a small fraction of one per cent. For example, in the case of the three-inch separator, if the velocity of flow is not more than one thousand feet per minute, with twenty-seven per cent of moisture in the steam entering the separator, there is practically no moisture in the steam which leaves it. If, therefore, a small "throttling calorimeter" be applied to the steam main at the exit from such a separator, the small amount of moisture there, and the fact that it will be thoroughly intermingled with the steam, make it reasonably certain that its indications will be correct for any arrangement of nipple, and, by combining these with the determinations of drip from the separator, the moisture in the steam generated by the boiler may be completely and reliably determined.

The author gives full descriptions of the tests made, the apparatus used and the methods of computing the moisture.

TABLE XXII.

TESTS WITH UNIFORM PERCENTAGE OF MOISTURE FOR CALIBRATION OF TWELVE-INCH DRUM *N*, PLATE *A*, FOR USE ON A LARGE "THROTTLING CALORIMETER."

Duration of Experiments.	Pounds of Dry Steam per hour.	Horse-power at 30 Pounds of Steam per hour.	True Percentage of Moisture by Weight. Entering Separator.	True Percentage of Moisture by Weight. Leaving Separator.	Per Cent. of Moisture at 12" Drum.	Boiler Pressure, Pounds.	Degrees of Superheating, Fahrenheit.	Temperature of Water Leaving Separator, Degrees Fahrenheit.	Number of Group.
	1	2	3	4	5	6	7	8	9
Av'ge of 5 experiments aggregating 150 min.	608.0	20.27	27.0	-0.03	-0.14	80.14	26.84	322.64	1
" " 3 " " 80 "	1537.8	51.26	21.5	2.17	1.87	81.13	27.23	324.40	2
" " 2 " " 80 "	1629.6	54.32	16.7	0.95	0.90	79 85	37.85	323.68	3
" " 2 " " 70 "	1749.3	58.31	12.7	0.54	0.45	79.85	36.95	323.58	4
" " 2 " " 60 "	1836.1	61.20	14.4	0.75	0.35	80.00	42.85	323.60	5
" " 2 " " 38 "	2109.2	70.31	30.3	2.20	2.05	79.75	34.25	323.35	6
" " 2 " " 50 "	2315.3	77.18	30.7	2.40	2.10	79.90	25.70	323 55	7
" " 1 " " 31 "	3033.9	101.13	7.7	0.21	0.30	80.00	27.70	323.90	8

TABLE XXIII.

Percentage of Total Moisture Entering a Three-inch Horizontal Steam Pipe that is Removed by a One-half-inch Drip Pipe.

The moisture in each case was either thoroughly mingled with the steam or the greater part of it was near the top of the three-inch pipe at a point eight feet distant from the one-half-inch drip pipe. Much of the moisture had, therefore, to fall through a distance nearly equal to the diameter of the three-inch pipe before it was drawn out at the one-half-inch drip pipe.

Conditions under which the Tests were Made.	Number of Test.	Velocity of steam in three-inch pipe in feet per second.	Percentage of Moisture in Steam Passing Through Three-inch Pipe. Before reaching drip pipe.	After passing drip pipe.*	Percentage of total moisture removed by the half-inch drip pipe leading to the Barrus calorimeter.
1	2	3	4	5	6
First Series of Tests. Moisture produced by the cooling pipe marked B in Fig. 1. No mixing device at D.	1	65.1	3.9	2.2	45.6
	2	64.7	1.9	0.9	55.7
	3	63.3	1.5	0.4	71.7
	4	52.3	1.6	0.3	84.4
	5	52.2	4.2	1.6	62.8
	6	41.9	3.3	0.3	91.5
Second Series of Tests, in which a mixing device was placed at D to thoroughly mingle the steam and water.	7	38.1	4.8	0.6	88.6
	8	38.1	2.6	0.5	82.8
	9	38.1	2.4	0.4	85.6
	10	38.1	0.3	0.0	100.0
	11	38.0	1.6	0.2	89.0
	12	38.0	0.4	−0.1	100.0
	13	24.9	4.8	0.1	98.7
	14	24.8	3.1	−0.1	100.0
	15	24.5	8.2	0.5	95.0
	16	19.2	8.8	0.5	95.3
	17	16.0	8.8	0.3	97.4
	18	16.0	6.6	0.1	98.1
	19	15.9	1.0	−0.1	100.0
	20	15.6	5.4	−0.1	100.0
Third Series of Tests, in which the steam and entrained moisture was supplied through a vertical three-inch pipe and flowed through an elbow into the horizontal three-inch pipe.	21	43.1	3.5	1.2	67.3
	22	42.7	2.3	0.7	68.8
	23	35.9	1.3	0.2	85.2
	24	35.8	3.4	0.7	80.8
	25	31.1	3.5	0.3	91.7
	26	31.1	2.1	0.1	95.0
	27	20.9	12.1	0.5	96.8
	28	20.6	7.8	0.0	100.0
	29	20.5	2.5	−0.1	100.0
	30	20.2	3.8	0.1	97.1
	31	15.8	5.6	−0.2	100.0
	32	15.4	8.7	−0.2	100.0
Special Tests in Third Series, in which a plate was placed over the drip pipe leading to the calorimeter so as to collect all moisture that was near the bottom of the pipe.	33	42.1	3.5	1.1	66.6
	34	42.1	2.2	1.2	49.4
	35	41.9	2.4	1.1	57.4
	36	38.1	2.4	0.6	77.8
	37	34.3	2.5	0.1	96.7
	38	33.1	3.4	0.0	100.0
	39	26.9	7.3	−0.1	100.0
	40	26.8	4.8	0.0	100.0
	41	20.5	4.3	−0.1	100.0
	42	20.2	13.1	0.4	97.4
	43	20.2	4.9	0.0	100.0

* The percentages of priming given in this column are calculated from the superheating in the twelve-inch drum, and are correct to within about one-fifth per cent. The minus values are either accidental discrepancies or they are caused by the fact that the steam was initially superheated, and tended to retain the property of producing a slightly higher "normal reading" than that given by the theoretical formula.

TABLE XXIV.

COMPARISON OF ACTUAL PERCENTAGES OF MOISTURE WITH AMOUNTS INDICATED BY A "THROTTLING CALORIMETER," STEAM PASSING THROUGH A THREE-INCH HORIZONTAL PIPE.

Number of test.	Character of Nozzle.	Steam passing through pipe per hour including moisture shown in Column 6.	Pressure of steam in pounds per sq. inch above atmosphere.	Percentage of moisture by Barrus calorimeter.	Correct percentage of moisture determined by weighing water injected into ste'm pipe.	Remarks.
1	2	3	4	5	6	7
1	Vertical nozzle No. 1 with 12 holes $\frac{7}{32}$ inch diameter.	1698	80	5.5	2.5	Separator of calorimeter, and heat gauge, both in use.
2		1877	80	9.3	3.3	
3		1768	80	11.1	4.7	
4		1788	80	20.9	10.9	
5		2003	80	31.8	19.1	
6		2381	80	47.9	36.5	
7	Horizontal nozzle No. 3 with 6 holes $\frac{7}{32}$ inch diameter.	1538	90	6.3	2.3	
8		1586	80	8.4	3.2	
9		1525	80	14.6	8.8	
10		1637	80	17.8	10.1	
11		1745	80	37.4	23.0	
12		2187	80	46.9	37.2	
13	Nozzle No. 4, slot away from current	1577	80	5.6	1.0	
14	" " " toward current...	1576	80	0.1	1.4	
15	" " " at right angles to current..........................	1578	80	2.5	1.2	Only heat guage of calorimeter in use
16	Horizontal nozzle No. 3 with 6 holes $\frac{7}{32}$ inch diameter.*	1810	80	1.0	0.5	
17		1815	80	1.5	0.8	
18		1818	80	2.2	1.0	
19		1830	80	3.6	1.6	

*In these tests the true percentages of moisture given in Column 6 were calculated from the superheating of the steam in the 12-inch drum, which was shown to give the same results as those obtained by weighing the water injected.

NEW FORMULA FOR THE FLOW IN SEWERS AND WATER MAINS.

BY W. S. CRIMP AND C. E. BRUGES.

(*Proc. Inst. C. E., London, Vol. CXXII.*)

The fundamental formula relating to the flow of liquids in channels is that of Chezy, in which $v = c\sqrt{rs}$, where v is the mean velocity in feet per second, r is the hydraulic mean depth, s is the surface inclination, and c is a coefficient. In this formula the frictional resistances are supposed to be proportional to $\sqrt{r}$, although recent research has shown that the resistances are not proportional to that power of r, but to other powers which depend upon the roughness of the wetted surface and upon other factors. This has been met in some later formulas by giving to the coefficient c a variable value, usually involving r, while the $\sqrt{r}$ is retained in the formula.

The authors have endeavored to construct a simple formula with

only one coefficient for all sizes of channels, if of good brick work or of cast iron, which should be sufficiently accurate for every practical purpose and yet should give results closely approximating to those obtained by the use of the more elaborate formulas of Messrs. Darcy and Bazin, and of Messrs. Ganquillet and Kutter. This was found to be not difficult when once the square root of the hydraulic mean depth as a measure of frictional resistance was abandoned and some other power of r was substituted for it.

In determining the influence of the hydraulic mean depth on the mean velocity, it is necessary to have a complete series of experiments under precisely similar conditions as regard inclination and roughness of surface with varying values of r. In order to obtain a suitable power of r the authors plotted a series of experiments, by Messrs. Darcy and Bazin, on semi-circular channels having a gradient of 1 in 666.67, Fig. 48. In the same figure are also plotted two curves, one involving $\sqrt{r}$ and the other $\sqrt[3]{r^2}$, from which it is apparent that, as a measure of frictional resistance, the latter function so nearly approaches the experimental results that it may be adopted as the base of a new formula. The authors prepared a series of diagrams to show that plotting the formula $c \sqrt[3]{r^2} \sqrt{s}$, with a suitable constant coefficient c, a curve is produced which compares favorably with those plotted from the formulas of the best authorities. Before deciding upon a value for c in the formula proposed, the authors plotted a number of trial curves and finally adopted 124, because it was found to give a very close approximation to the curves of Darcy's and of Kutter's formulas for channels constructed of materials like those under consideration.

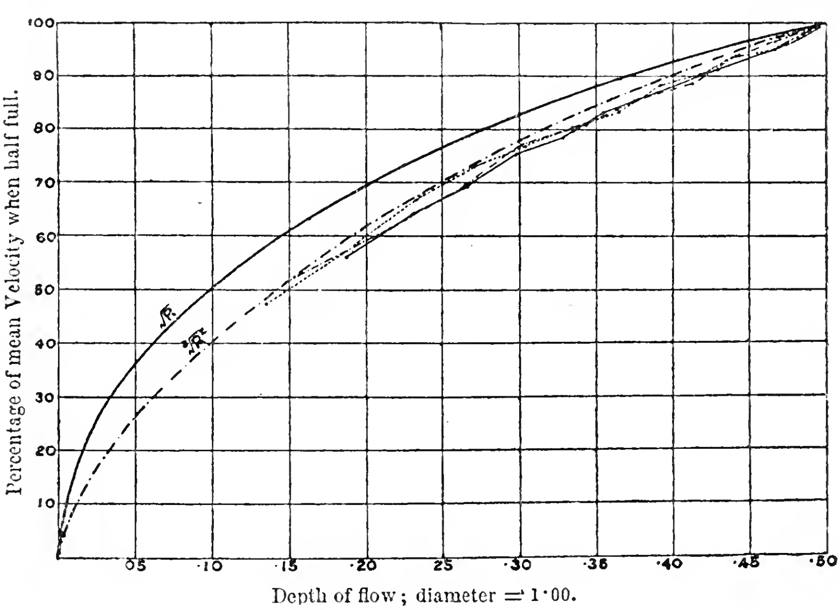

Fig. 48.

Experiments of Darcy and Bazin on semi circular channels at various depths of flow, reduced to show the percentage of the mean velocity when half full, and showing comparison with formulas based on $\sqrt{R}$, and those based on $\sqrt[3]{R^2}$.

The author's formula, proposed for application to sewers and iron water pipes, is:

$$v = 124 \sqrt[3]{r^2} \sqrt{s}.$$

A closer approximation might be obtained by the adoption of another coefficient with a different power of s; but as for every day use it is advantageous to possess a formula which can be employed without reference to tables, the authors prefer the simple form given.

Details of a number of experiments conducted by Mr. Crimp are given. In conclusion the authors say that so far as the materials mentioned are concerned, calculations by the proposed formula will give trustworthy results, erring, if at all, on the side of safety.

C. E. B.

MEANS ADOPTED FOR SAVING FUEL IN A LARGE OIL REFINERY.

By Chas. E. Emery.

(*Advance Proof, Trans. Am. Soc. M. E., December, 1895.*)

In the refinery referred to there were 5,500 horse power of boilers installed in four boiler houses in different parts of the grounds, which boilers were originally forced much beyond their capacity a great deal of the time. The coal consumption for steam purposes amounted to about 64,000 tons per year, independent of which a very large quantity was consumed directly under stills.

An investigation was made of the cost of power used by the large pumps of the refinery, the method generally adopted being to ascertain the weight of exhaust steam either by a temporarily arranged surface condenser or exhausting directly into a vessel of water, the water used being compared directly with the theoretical power obtained from the gallons pumped and the pressure of delivery. It was found that many of the steam pumps were using as high as 240 pounds of water per net horse power per hour, and only in exceptional cases could one be found which could deliver a horse power as low as 80 pounds of feed water. Exhaust steam pipes were being erected and connected so as to keep the various stills and tanks warm during the winter. The preliminary report of the author recommended electric transmission to reach various outlying points where steam had to be transmitted a long distance; an extension of the exhaust system even if it became necessary to increase the back pressure; the establishment of a number of power stations in which would be erected good high pressure non-condensing engines, operating power pumps to take the place of the numerous steam pumps, the exhaust from such engines to be used for heating purposes.

The suggestions were adopted, and at the present time the system of local plants operated by high pressure steam engines and power pumps has been applied at two points in neighborhoods where the least exhaust steam is required. The result of the work thus far accomplished has been to reduce the coal consumption for steam purposes fully one-half, or about 32,000 tons per year. The principal part of the saving has been due to the use of exhaust steam.

C. E. B.

CYLINDRICAL BRIDGE PIERS; NEW ZEALAND MIDLAND RAILWAY.

By H. W. Young and W. C. Edwards.

(*Proc. Inst. C. E., London, Vol. CXXII.*)

Most of the bridges in New Zealand cross streams which are subject to floods carrying large quantities of driftwood, and which flow in channels of shingle or other alluvial drifts, subject to constant change from the processes of scour and deposit. For first-class bridges, piers consisting of two cylindrical columns ranging between $4\frac{1}{2}$ feet and 8 feet in diameter, have been extensively adopted for upwards of twenty-five years. The authors give some account of the methods, processes and plant used in cylindrical bridge piers built since 1887 on the New Zealand Railway. The bridges consist of series of 66-foot lattice, or plate girders, supported on piers composed of two columns of cast iron cylinders 4 feet 6 inches in internal diameter, sunk with the aid of pneumatic pressure and filled with concrete. The bases of some of these columns are enlarged by taper pieces with 6-foot cutting rings, while others are $4\frac{1}{2}$ feet in diameter throughout, excepting where the cutting edge projects to 5 feet.

The metal in all cylinders is $1\frac{1}{8}$-inch thick, the junction ends having feathered flanges with bolt-holes. The joining edges of the ends of the cylinders project slightly beyond their flanges, and are machined so that they fit neatly together and in accurate alignment. The flanges of joining rings do not meet, as the edge projections cause a space between them, which is securely packed so as to be air and water tight, the flanges being fastened together with 1 inch bolts. The highest cylinder ring, which has no flange on its upper end, is of suitable length to complete the required height of column, and is finished with a capital which slips over and is bolted to it, a few inches of adjustment for height being possible. The capital is kept in position by distance studs and bolts, and is thoroughly secured by the concrete filling. With cylinders of larger diameter, or where the weight of the pieces is limited by conditions of transport, the rings are cast in segments having vertical joints similar in construction to those between the rings. As the smaller cutting-rings, used where the nature of the foundations and the height of the piers permitted, were to some extent experimental, it may be interesting to compare their advantages with those of the larger rings. The former saved about £50 per pier in concrete and iron, exclusive of the saving due to the reduction of excavation by two-sevenths. The cutting-rings of an internal diameter of 6 feet allow two men to work on the bottom, while those $4\frac{1}{2}$ feet in diameter give room for only one man. In certain strata it is expedient to have two men in the bottom while sinking a cylinder. In three bridges experience was distinctly in favor of the smaller rings and proved that they can be used with advantage under fairly favorable circumstances.

In the construction of the piers, the essentials may be classed

under the heads of staging with hoisting gear, pneumatic plant and appliances, placing and erecting, loading, sinking and filling with concrete.

The staging usually consists of two combined structures, one comprising the framework necessary for guiding and controlling the cylinders, each formed of six driven piles with caps and framings, and collectively called the "pig-sty;" the other consisting of piles and framing to carry necessary cranes or traveler.

The air lock is the most important feature of the pneumatic plant. It is cylindrical in form, constructed of $\frac{3}{8}$-inch boiler-plate, stayed and strengthened, furnished with a door on the side, a manhole in the floor giving access to the cylinder, two reversible shoots projecting outside from opposite sides of the chamber, and the necessary air-piping, stop-cocks, pressure-gauge and dead lights. The windlass is worked from the outside, being contained in an air-tight casing bolted on the top of the chamber, the axle passing through the casing in air-tight packings. The two shoots are essential to rapid work. They are simply iron tubes, rectangular in section, with movable air-tight end glands, and are constructed so as to be reversible with either a downwards or an upwards slope from the air-lock. The glands and clamping bolts have rubber packings, and are easily fixed or removed. Those for the air-lock openings run up and down in slides within the chamber, and are balanced by counterweights hung on light wire ropes attached to the glands and passing over pulleys. The glands at the outer ends of the shoots are hinged so as to open clear, and are fastened when closed by a hinged clamping-bolt. The manhole door on the side of the air-lock is hung and closed in a similar manner. The door between the air-lock and the cylinder is hinged to open downwards, and is closed and fastened from above by a clamp-bar. All the air-pipe arrangements can be manipulated within the air-lock, and means are provided for letting air in or out of the air-lock and cylinder respectively. A life-line secured and kept within the air-lock is provided in case of sudden flooding of the cylinder or of accident to the winch or rope. The bed-plate is a casting bolted to the flanged bottom of the air-lock and to the top flange of the cylinder.

When working the air-lock a man remains inside, and the chamber is kept under pressure with the door open between it and the cylinders, except when men pass in or out at changes of shift or at other times. The cylinders are, if possible, kept constantly under pressure. When excavated material is passed out, the air-lock man sends down the empty bucket, the windlass being worked by the men outside according to his signals; and on its return full he tips it into one of the shoots, which is then open at the chamber end and closed at the other. Whenever one shoot is full, the air-lock man closes and secures the gland at his end, and signals to the attendant outside, who opens the discharge end and empties the shoot, having previously prepared the other shoot for filling. The air-lock man after filling and closing one shoot, opens and fills the other, and by this alternate use of the two shoots, the work is proceeded with

continuously without alteration of the air-pressure. Under fairly favorable conditions, the windlass is thus kept constantly going, and sinking proceeds as quickly as in an open shaft. Four men are required, exclusive of sinkers, one being in the air-lock, two at the windlass, and one attending to the shoots and to the guidance of the cylinder.

The cutting-ring being adjusted in position, other rings with air-tight joints are bolted to it until a column is built, passing up through the "pig-sty" framing and above the staging to the greatest convenient height. The column is then carefully plumbed and secured in a vertical position by the framing and wedges. The tubing and concrete kentledge subsequently described is inserted as the building proceeds, and is completed so far as is necessary; after which, if possible, it is left for a short time to give the concrete time to set. When the column is ready for use the air-lock with necessary connections is properly secured to the upper flange. If the cylinders have to be pitched in water, the cutting-ring and a convenient number of other rings are put together in the "pig-sty" above the water-level. The column thus constructed is carefully lowered and guided into its exact position, and completed as in the previous case, excepting that the tubing and loading are executed under pressure. When pitching a column in a strong current of water, it should be placed a few inches up stream from its true position and afterwards moved down by wedging. If placed out of position down stream its adjustment is difficult. To prevent the cylindrical column from being forced upwards by air-pressure, and to insure its descent as the sinking proceeds it is loaded until it overcomes skin-friction and other resistance, whilst yet thoroughly under control so that it may be readily hung up when necessary. If the loading is insufficient, the column may be lifted with an increase of air-pressure or may fail to descend as the excavation below it is performed, in which case an inrush of drift may occur if the ground is loose. Under favorable conditions concrete loading is sufficient, but where more weight is necessary, rails or other available materials are placed on staging attached to the air-lock bed-plate.

In applying the concrete loading which forms part of the permanent filling, a feature called "the bell" is first formed. This is done by setting up an internal frame of "bell-irons," consisting of 2x$\frac{3}{8}$ iron bolted to the flange of the cutting-ring joint, sloping upwards at an angle of 60 degrees towards and bolted to an angle-bar ring 2x2x$\frac{3}{8}$ and 18 inches in diameter, placed horizontally in the middle of the cylinder. Tapering lagging boards 1 inch thick are then laid over the sloping iron frame which connects the flange of the cylinder with the ring, and upon the lagging concrete is laid. A length of tube, 18 inches in diameter, made of 3x1 timber staves, 6 feet long, bound with light hoop iron, is then set up above the central ring and is kept concentric with the cylinder. The annular space between the tube and cylinder is filled with concrete, another similar length of tube and concrete work is constructed, and so on until the required height is reached. The bell irons, lagging, and

tubing remain until the sinking is completed, when they are taken out. It is advisable to use more cement in making the loading than is required for ordinary concrete. A safe height should always be left between the bottom of the cutting-ring and the bell, especially where sand or soft material may be met with; otherwise a sudden drop of the column would be dangerous to the men engaged below.

The concrete for filling the cylinders is mixed on the air-lock staging. When filling cylinders, the air-lock shoots are reversed so as to incline upwards, and the concrete is passed in by operations similar to those used in passing out the spoil. C. E. B.

WATER-POWER; ITS GENERATION AND TRANSMISSION.

By Samuel Webber, Charlestown, N. H.

(*Advance Proof, Trans. Am. Soc. M. E., December, 1895.*)

The author gives a large amount of historical information concerning the use of water-power in the United States, including a short history of the development of the turbine. The paper closes with some estimates and data as to cost per horse-power per year in three different localities:

"When we come to the matter of cost, we find it to vary much in different localities, according to the expense of development. The cost at Lowell, when the first 'mill powers' were opened, had been only $40 per horse-power, for dam, land, and canals. This was increased $50 per horse-power by the new canal, which gave more certain head, and enabled the mills to use the surplus water which ran to waste part of the year, and the total cost has probably been $100 per horse-power, to which another $100 is to be added for the expensive Boyden wheels and massive masonry pits. At Augusta, Ga., the canals, nine miles long, cost the city, which leases the power, $90 per horse-power. At Columbia, S. C., for five miles of canals the cost to the city has been $72 per horse-power. In many cases of smaller enterprises it has been less than $50 per horse-power, and the total cost, including wheels and pits, less than $100.

"The Concord Water Power Company, on the Merrimac River, at Concord, N. H., develops a minimum of 3,300 horse-power, an average of 5,000 horse-power, from a fall of 22 feet. The wheels are 'Rodney Hunt' turbines, set in pairs on horizontal shafts of 400 horse-power each. The cost has been as follows:

700 acres Land, and Flowage Rights	$20,000
Dam and Abutments	141,015
Canal, 60 feet wide	27,363
Head Gates	16,675
Waste Weir	5,220
Making an investment for water of	$210,273

or $63.72 for the minimum amount of power, or $42.05 for the average amount of power. To this is to be added, pits and foundations put in for 2,000 horse-power, $15,000, or $7.50 per horse-power. Wheels put in for 1,600 horse-power, $12,225, or $7.66 per horse-

power, making a total, for the minimum flow of water, of $78.88 per horse-power, and for the average flow, of $57.75 per horse-power.

"Now, if we base our calculation of cost on the minimum flow, and allow interest, 5 per cent; sinking fund, 2½ per cent; repairs, 1½ per cent; taxes, etc., 1 per cent, we get a total annual cost of 10 per cent, or $7.89 per horse-power, to which add oil and attendance, 75 cents, making $8.64.

"As this power is to be transmitted, in part, at least, to Concord by electricity, the cost of such transmission, on which I do not assume to be authority, will have to be added to this. If, on the other hand, it is to be partially used near at hand, it is safe to say that the cost of transmission by shafts and belts would not increase it to over $10 per horse-power.

"If we assume the average flow of 5,000 horse-power the cost of the power at the wheels would be only $5.72, but we should then require the additional expense of a steam plant, and its operation, to produce the 1,700 horse-power deficiency at low water.

"At the mill of John P. King, at Augusta, Ga., the water is purchased of the city at a rental of $5 per annum per gross horse-power.

"The wheels are three Geyelin turbines, on vertical shafts with bevel gears, estimated at 1,835.5 gross horse-power. These wheels, by my own test in situ, netted 84 per cent. Calling the average 80 per cent it gives 1,468 net horse-power. This cost of plant was for wheel-pits, 42 feet deep, in rock, head race, 200x40, tail race, 800 feet to river, about $25,000, and the wheels and jack shaft cost the same, or $50,000 in all. This, for 1,468 net horse-power, is $34.20 per horse-power, or, at 10 per cent, $3.42; water rent, $5.50 on 1,835.5 gross horse-power, equal, net, $6.88; attendance and oil, 75 cents, making a total cost of $11.05.

"The next case is also a southern one, that of the Columbia Mills, at Columbia, S. C. Here the water is also leased at a rental of $5 per horse-power. For quantities less than 500 horse-power, the charge is $7. The fall is 27 feet, and the power is furnished by Victor turbines, on horizontal shafts, and is transmitted by electricity to the mills.

"Quicksands made the wheel-pits very expensive, by the quantity of concrete masonry required, so that for all expenses of pits, races, power-house, etc., we have $55,000 for 2,000 horse-power. The wheels cost $20,000 more, so that we have a total expenditure of $75,000 for 2,000 horse-power, or $37.50 per horse-power. This, at 10 per cent, as before, gives $3.75 per horse-power; water rent, $5 per horse-power; attendance and oil, 75 cents; making a cost at wheels of $9.50 per horse-power.

"As the water rent paid in the last two cases covers interest and depreciation, while the cities which furnish the water also obtain their own supply for other purposes, it will be seen that it covers the cost, and that the estimate of Mr. Samuel Batchelder, fifty years ago, that the cost of water-power, in Lowell, including land, was under $15 per annum per horse-power, was substantially correct, and will cover the cost of water-power with modern turbines, under fair circumstances, to-day, with plenty of room to spare for heating."

C. E. B.

RECENT IMPROVEMENTS IN LOCOMOTIVE DESIGN.

By W. Rowland.

(*Abstract Trans. Liverpool Engineering Society, Vol. XVI.*)

Although in its essential parts the locomotive has undergone little modification during the past forty-five years, still the machine in use to-day has many improvements over those of twenty years ago, and this paper is a resume of the progress on the London & North Western Railway.

The locomotive is an ill-used machine, on account of the great variations of its duty, the exposure of its parts and the adverse conditions which must be met by its design. On this account it deserves great credit for its efficiency.

During the last twenty years greater demands have been made on locomotives on account of both the increase in weight and speed of trains. The limited Scotch mail in 1864 had 8 coaches weighing 54 tons, and in 1884 13 coaches weighing 165 tons. One unscientific and uneconomical method of meeting this difficulty is by double engine running. It is unprofitable also to work an engine at its maximum power on account of the excessive wear on the engine and the uneconomical use of the fuel.

The right course is to build engines in proportion to their work, and in this the designer is restricted by the limitations of gauge, weight, etc.

Up to 1874 the standard express engine for heavy work had 4 coupled wheels 81 inches in diameter, and 2 leading wheels 43 inches in diameter. It had 17x24-inch cylinders placed between the frames, 28 inches between centers. The valves were between the cylinders. The steam pressure was 120 pounds per square inch, and journals of driving axles were 7x7 inches. The total weight was 70,000 pounds, of which 48,832 pounds was on drivers.

In 1874 Mr. Webb designed a more powerful engine of the "Precedent" class, which has been very satisfactory. It had inside cylinders 17x24 inches, 24 inches on centers, with the steam chests above them, and the valve faces at an angle of 30 degrees, with the vertical plane. The journals of driving axles were 7x9 inches. The Allen straight link was employed, which gives a constant lead. The steam pressure was 150 pounds per square inch, and diameter of boiler at first sheet, 48 inches. There were 194 tubes $1\frac{7}{8}$ inches in diameter. The throttle valve was placed on the front tube sheet. Some of the principal dimensions were:

Diameter of drivers, 81 inches.

Length of firebox, 4 feet $10\frac{5}{8}$ inches.

Width of firebox, 3 feet 6 inches.

Depth of firebox, 5 feet $9\frac{1}{4}$ inches.

Heating surface of firebox, 103.5 square feet; heating surface of tubes, 960.2 square feet; total, 1063.7 square feet.

Grate area, 17.1 square feet.

Driving wheel base, 8 feet 3 inches.

Total wheel base, 15 feet 8 inches.

At present 166 engines of this class are in operation, and 70 with 6 foot driving wheels.

In 1878 Mr. Webb built his first compound by bushing to 11 inches one cylinder of an old engine with $15\frac{1}{2}$x24 inch cylinders, and providing a starting valve for the low-pressure cylinder.

The success of this engine led to the design of a compound for main line traffic to take the place of the "Precedent" class. This system of compounding, known as the "Webb system," is well known and consisted of two outside high-pressure cylinders operating the rear drivers, and one inside low-pressure cylinder operating the forward drivers. The two H. P. cylinders were first made 11 inches in diameter, but were afterward increased to 13 inches, the L. P. cylinder being 26 inches in diameter. The stroke of both was 24 inches. Many of the dimensions of this engine were the same as the "Precedent" class, and the steam pressure was the same, but the total wheel base was lengthened by moving the leading wheels ahead. The framing of the two classes was somewhat different. The H. P. cylinders had their valves beneath them, while the L. P. cylinder had its valve above, the valves being operated from their respective driving axles. There were no side rods. The Joy valve motion was employed for both H. P. and L. P. valves at first, but later this was superseded by a loose eccentric arrangement for the L. P. valve. The throttle valve was placed in the dome. The boiler was mild steel, and steel castings were extensively used. The total weight in working order was 84,560 pounds, of which 54,432 pounds was on drivers.

The working of this engine was very satisfactory. In hauling the limited Scotch mail the average coal consumption per train mile was 26.6 pounds against 34.6 for the standard simple engine.

In 1884 Mr. Webb built the "Dreadnaught" class of compounds, with cylinders 14 inches and 30x24 inches. The general arrangement of cylinders and motion was the same as the preceding class, but there were a few differences in the details. The leading axle was moved back behind the low-pressure cylinder, the driving wheel base increased to 9 feet 8 inches, and the diameter of drivers reduced from 81 inches to 75 inches. The firebox, 6 feet 10 inches in length, was probably the largest in use in Great Britain. The boiler pressure was increased to 175 pounds, the boiler was steel, and the crown sheet stayed with crown bars. The driving axle boxes had each four underhung, double-coil, helical springs. Some of the principal dimensions were:

Length of engine over all, 27 feet $1\frac{1}{4}$ inches.
Diameter of leading wheel, 43 inches.
Diameter of forward drivers, 75 inches.
Diameter of rear drivers, 75 inches.
Total wheel base, 18 feet, 1 inch.
Driving wheel base, 9 feet, 8 inches.
Journals leading axle, $6\frac{1}{4}$x12 inches.
Journals driving axles, 7x$13\frac{1}{2}$ inches.
Diameter of boiler shell, 51 inches.
Number of tubes, 225.
Diameter of tubes, $1\frac{7}{8}$ inches.

Heating surface of firebox, 159.1 square feet; heating surface of tubes, 1,242.4 square feet; total, 1,401.5 square feet.

Grate area, 20.5 square feet.

Weight on leading wheels, 26,880 pounds; weight on forward drivers, 33,600 pounds; weight on rear drivers, 33,600 pounds; total, 94,080 pounds.

On March 19, 1885, No. 503 took the Scotch express, weighing 139.1 tons, 300 miles at an average speed of 44.7 miles per hour, with a coal consumption of 29.2 pounds per train mile and an evaporation of 9.49 pounds of water per pound of coal.

In 1889 Mr. Webb brought out the "Teutonic" class of compounds, which is almost exactly similar to the preceding with the exception of the wheels, which were 49½ inches and 85 inches in diameter. The weight was also slightly greater, being:

On leading wheels, 32,480 pounds; on forward drivers, 34,720 pounds; on rear drivers, 34,720 pounds; total, 101,920 pounds.

Ten of these engines have been built and have shown a distinct improvement over their predecessors.

In 1891 another class of compounds, with 15 inch and 30x24 inch cylinders was designed, to which belongs the "Greater Britain," and which had four drivers, two leading wheels and two trailers. The rear driving axle was moved up ahead of the fire-box, the size of the wheels remaining the same as in the "Teutonic" class. This arrangement necessitated a longer boiler, which had a steel combustion chamber, semicircular in section, and 2 feet 10 inches long. The distance from front tube sheet of boiler to the front tube sheet of this combustion chamber was 10 feet 1 inch, and from fire-box tube sheet to rear tube sheet of combustion chamber was 5 feet 10 inches. The ordinary link motion was employed for the H. P. valves, and the loose eccentric for the L. P. valve. The H. P. steam chests were inside the frames. There were 312 tubes, 156 on each side of the combustion chamber:

Heating surface of firebox, 120.6 square feet; heating surface of combustion chamber, 39.1 square feet; heating surface of tubes, 1,346.0 square feet; total, 1,505.7 square feet.

Grate area, 20.5 square feet.

Owing to the arrangement of the H. P. steam chests the double plate frame was abandoned for a single plate one.

Plate springs for both leading and trailing wheels were employed, the former being above, and the latter below, the boxes. The driving springs are double coil helical, and are underhung. The boiler pressure was 175 lbs. per sq. in. as before. The distribution of weight was:

On leading wheels	28,672 lbs
On forward drivers	34,720 lbs
On rear drivers	34,720 lbs
On trailers	18,592 lbs
Total	116,704 lbs

These engines have given every satisfaction in running, both as regards steadiness at high speed and fuel consumption.

An engine similar in every respect, except in having leading and

trailing wheels 43 in. in diameter and drivers 75 in. in diameter, was put to work in April, 1894.

In the early part of 1894 Mr. Webb made a comparative test between a heavy compound and a simple freight engine. Every precaution was taken to insure similar conditions, and the saving in coal was 23.38 per cent in favor of the compound, which also used 34.5 per cent less water.

The simple engine was a 19½x24 in. eight wheel engine, with all wheels coupled. The wheels were 51½ in. in diameter, and the first three pairs were equalized. The compound engine had two 15 in. outside H. P. cylinders and one 30 in. L. P. inside, the common stroke being 24″. Unlike other compounds of Mr. Webb's, the three cylinders were in line, and all drove the second axle from the front. The two H. P. cranks were set at right angles to each other and the L. P. at 135 dgs. to both. There was no combustion chamber. Link motion reversing gear was used for the H. P. cylinders and the loose eccentric for the L. P.

The following features are common to the engines described, as well as to other engines on the London & North Western Railway:

The leading axle is carried in radial axle boxes. This box is formed of a single casting resembling a curved inverted trough having the brasses fitted at each end. It works between curved guide plates stretching across between frames and is free to travel across the engine between these plates as well as to move vertically. The springs are of the ordinary plate type hung over each bearing. There is one compound controlling spring restoring the axle box to its central position. It is placed between two circular castings running on a spindle passing through the spring and bearing against a cast steel frame bolted between the radial plates of the engine framing. When the axle box is moved to the right, the left hand casting is forced against this bearing, compressing it and tending to restore the axle box to its original position.

The low-pressure valve is driven by a single eccentric which is loose on the shaft and has two stops for forward and back gear respectively, the sheave being balanced. To reverse the motion, it is therefore necessary for the engine to make a portion of a turn in the direction in which it is about to run so that the low-pressure system does not come into action until the engine is moved a few feet. In order to prevent the exhaust from the H. P. cylinder entering the low-pressure steam chest before this eccentric has reversed itself, a valve it fitted to the blast pipe, allowing the steam from the receiver pipes to exhaust directly into it. This valve is worked from the cab.

Steel castings have replaced forgings and iron castings in many places. The large 30-inch pistons for low-pressure cylinders are of cast steel. They are cast in one thickness and are very light, being only 265 lbs. in weight. Built up balanced crank axles are also used, having the webs, balance and pin cast in steel in one piece. The brake in use on the London & North Western is the automatic vacuum in combination with an automatic steam brake on engine and tender.

Phosphor bronze is the material usually employed for slide valves, although some engines have cast iron valves on a phosphor bronze false seat.

D. L. B.

GENERAL ORLANDO M. POE.

A MEMOIR.

A great and deeply felt loss was sustained by our society as well as by the Corps of Army Engineers, by the engineering profession at large, and by the people of the Northwest, in the sudden death, on Wednesday, October 2, 1895, of Gen. Orlando M. Poe, of the Corps of Engineers, U. S. Army, at his home, 131 Congress Street, Detroit, Michigan. His death was caused by erysipelas following a fall sustained a few days before during a visit to the St. Mary's Falls Canal.

Orlando Metcalf Poe was born in Marane, Stark County, Ohio, March 7, 1832, and spent his early life upon a farm, where he earned his first money by working in the field for five dollars a month. With his first month's pay he purchased three books: a grammar, an arithmetic, and a book on literature, and from these three he secured the beginning of his education. His energy and perseverance were clearly demonstrated at this early period, for while he worked in the field during the day to supply his physical wants he studied at night to satisfy his hunger for knowledge, with the result that he was soon selected for a teacher in the district school, whence he was appointed to a cadetship at West Point in 1852.

MILITARY RECORD.

Graduating from the military academy after the usual course of four years he was commissioned as brevet second lieutenant of the Corps of Topographical Engineers in 1856. At the outbreak of the war in 1861 he was assigned to duty in the organization of volunteer regiments in the State of Ohio. After a short period of service on the staff of General McClellan he was appointed colonel of the Second Michigan Volunteers September 16, 1861, and from that time until April, 1863, he was on duty with the Army of the Potomac and shared in the vicissitudes of the campaign of 1861-62. He was commissioned brigadier-general November 9, 1862, and continued in command of troops until April, 1863, when he entered upon the duties of a staff officer, acting as military engineer until the close of the war. He was chief engineer of the military division of the Mississippi after April, 1864, and had charge of engineering operations in the army of General Sherman during the advance on and attack of Atlanta, during the march to the sea and during the campaign which resulted in the surrender of the Confederate army under Gen. Joseph E. Johnston, April 26, 1865.

The value of his services was recognized by several brevets, as follows: Brevet major for gallant services during the siege of Knoxville July 6, 1864; brevet lieutenant colonel for gallant services in the capture of Atlanta September 1, 1864; brevet colonel for capture of Savannah December 21, 1864; brevet brigadier general for gallant and meritorious services in campaign terminating with the surrender of the insurgent army under Gen. Joseph E. Johnston, March 13, 1865.

BREVET-GENERAL ORLANDO M. POE,

COLONEL OF ENGINEERS, U. S. ARMY.

RECORD AS AN ENGINEER.

Although highly distinguished as a soldier, General Poe was equally prominent as an engineer in charge of large public works, and it is in this capacity rather than that of a soldier or military engineer that his record should be considered here. His first work in the line of civil engineering after graduating from West Point was in connection with the surveys of the Northern lakes, which continued until the outbreak of the war in 1861. After its close he served as secretary of the Light House Board from 1865 to 1870; as superintending engineer of river and harbor works in East Michigan from April, 1870, to May, 1875, during which period he also served as engineer of the eleventh light house district. He was a member of the Light House Board from January, 1874, to April, 1884. In August, 1883, he resumed charge of river and harbor works in East Michigan, in which he continued until his death. To this duty was added in 1888 that of division engineer for inspection of United States engineering works in the Northwestern territory of the United States. He also served as a member of a large number of boards of engineers, the principal ones being the following: To decide upon a site for harbor of refuge on Lake Ontario in 1871 to 1872; on locks of the Louisville and Portland Canal in December, 1871; on examination of the condition of Toledo harbor in December, 1872; on preservation of the Falls of St. Anthony in April, 1874; on selection of a site for a movable dam on the Ohio River in April, 1875, and on improvement of the Kanawha River May, 1875. One of his last official duties was that as a member of the Board of United States Engineers to consider and report on the probable effect of the Chicago Sanitary District Canal on lake levels. The official report of this board was completed and submitted to the War Department only a short time before his death, but he was not spared to see its recommendations executed.

During this entire term of public service the General was in charge of many notable works. He laid down the general lines on which the improvement of the St. Mary's Falls Canal was carried out in the years 1870 and 1883, and since his return to the lakes in 1883 he planned and constructed at St. Mary's Falls Canal the largest canal lock now in existence. He also planned and had nearly executed the improvement of the water communication through the lakes to afford a draft of twenty feet. The light house at Spectacle Reef in the northern end of Lake Huron was practically constructed by him between the years 1870 and 1873. This important structure, as regards the character of the work upon it and the difficulties of executing it, is fairly comparable with the more famous Eddystone light.

General Poe was a member of this society since 1871. His last relation with it was his appointment as a delegate to the International Deep Waterway Convention held in Cleveland, Ohio, last September. In a most kind and considerate letter to our secretary, but six days before his death, he expressed his regrets at not being

able to attend, owing to sickness—a sickness which, to the most intense regret and sorrow of thousands, was to be his last.

Among those who more directly and keenly felt the loss of the energetic and disinterested efforts of the late General were the vessel owners, navigators and others interested in the commerce of the great lakes. Many and solemn were the meetings of such bodies, and most expressive of sincere admiration were the resolutions adopted by them testifying in unqualified terms to the high esteem in which the General was held by them and to the great value of the many works planned and executed under his direction.

A considerable portion of the General's active life was spent in the light house service, which we may consider as peculiarly appropriate, for he himself was a bright and shining light among his fellow workers, a safe and trusted guide for others struggling on the unfathomable sea of engineering knowledge.

General Poe was a man who earned and received admiration in any station of life, not only as a brave and skillful soldier, as an engineer of rare ability, as an honorable executive officer of remarkable judgment and unquestioned integrity, but also as a highly respected citizen in ordinary life, amiable, unassuming and approachable, a model family man, a beloved husband and father.

General Poe married Miss Eleanor C. Brent, of Detroit, Mich., the 17th of June, 1861, in Christ's Church, of that city. Two hours after the ceremony the General left his bride to attend to official military duties under General McClellan, whose engineer he was at that time, and he was unable to return until two months later.

The General had four children: Orlando M. Poe, Jr., who died three years ago at the age of thirteen; Charles Carroll, a graduate of Annapolis Naval Academy, who died suddenly only last May; a daughter, Winifred, wife of Harry Fitzhugh, of Pittsburg, Pa., who had also died but eighteen months before the General's death. The only survivors of the General's immediate family are his widow and one daughter, Miss Elizabeth.

We heartily endorse the sentiment expressed by General Alger in the Detroit Free Press, which is a most concise and fitting tribute to the General's memory:

"General Poe needs no monument. His works and the improvements made under his direction are a grander monument to the memory of the man than any that could be erected."

(Signed) G. A. M. Liljencrantz.
Wm. T. Casgrain.
Alfred Noble.

In presenting this memoir on the life of the late Gen. O. M. Poe the committee desires to offer the following resolutions:

Resolved, That we, the Western Society of Engineers, hereby express our most heartfelt sorrow and regret at the loss of our highly esteemed fellow member and most eminent citizen; and further

Resolved, That we tender our sincere sympathy and condolence to his bereaved family; and further

Resolved, That this memoir and these resolutions be spread on the minutes of the society and copies thereof be tendered to Mrs. Poe and to the Chief of Engineers, U. S. Army.

Western Society of Engineers,

ROOMS, 1737 MONADNOCK BLOCK,

CHICAGO, ILLS.

OFFICERS FOR 1896.

PRESIDENT,

JOHN F. WALLACE.

FIRST VICE-PRESIDENT,

THOS. T. JOHNSTON.

SECOND VICE-PRESIDENT,

ALFRED NOBLE.

TRUSTEES,

ROBERT W. HUNT,
G. A. M. LILJENCRANTZ,
HORACE E. HORTON.

TREASURER,

EMIL GERBER.

SECRETARY,

CHAS. J. RONEY.

STANDING COMMITTEES,

Membership: ALFRED NOBLE, HORACE E. HORTON, E. GERBER.
Finance: ROBERT W. HUNT, L. P. MOREHOUSE, HIERO B. HERR.
Publication: J. J. REYNOLDS, THOS. T. JOHNSON, CHAS. E. BILLIN.
Library: G. A. M. LILJENCRANTZ, JOHN LUNDIE, FRANK KELLOGG.

MEETINGS

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: 1st Tuesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

The Annual Meeting (339th of the Society) was held at the Auditorium Hotel, Chicago, Wednesday evening, January 8th, 1896; 117 members and guests present. The meeting was called to order by President Horace E. Horton.

The minutes of the November and December meetings were approved as printed.

The Secretary read the following report of the Judges of Election:

Chicago, January 8, 1896.

To the Western Society of Engineers:

We, the undersigned Election Judges, appointed by the Board of Directors, having duly canvassed the vote cast for the election of officers for 1896, respectfully submit the following result:

Total number of votes received	165
Number of irregular votes, not counted	10
Total number of votes counted	155
Cast for President—	
John E. Blunt	6
John F. Wallace	146
Cast for First Vice President—	
Thomas T. Johnston	121
August Ziesing	32
Cast for Second Vice President—	
Charles E. Billin	54
Alfred Noble	98
Cast for Secretary and Librarian—	
Ralph Modjeski	8
Charles J. Roney	144
Cast for Treasurer—	
David L. Barnes	14
Emil Gerber	137
Cast for Trustee—	
H. E. Horton	113
John Lundie	40
Cast on Adoption of New Constitution—	
Yes	120
No	18
Cast for Adoption of New By-Laws—	
Yes	123
No	17

(Signed) ALEX. E. KASTL,
ROBERT P. BROWN,
T. L. CONDRON.

The President then declared the following officers duly elected:

President—John F. Wallace.
First Vice-President—Thomas T. Johnston.
Second Vice-President—Alfred Noble.
Secretary and Librarian—Charles J. Roney.
Treasurer—Emil Gerber.
Trustee—Horace E. Horton.

The President also declared that the revised constitution and by-laws had been adopted.

The following preamble and resolution, prepared by Mr. Isham Randolph, under instructions from the Society, were read and unanimously adopted:

Whereas, The Directory and Faculty of the Armour School of Tech-

nology extended to this Society a most hospitable and liberal invitation to use the Audience Hall of that institution for its meetings, and generously placed at its command the use of its electrical stereopticon and appliances for illustrating lectures, including the preparation of lantern slides for such illustrations; and, *Whereas*, Within the year last past this Society has accepted this generous hospitality upon several occasions, therefore *Be it Resolved* That the grateful sentiments of this Society be, and they are hereby tendered to the Directory and Faculty of the said Armour School of Technology in a vote of thanks for the privileges, the aid and courtesy so freely extended to its members and guests.

And, Further, This Society takes this occasion to express its appreciation of the educational work which is being done by this school and its earnest wish for the success of that work on the lines laid down by its projectors.

The Secretary was instructed to transmit a copy of this preamble and resolution to the President and Faculty of the Armour School of Technology.

The following preamble and resolution, offered by Mr. J. J. Reynolds, was unanimously adopted:

Whereas, The entertainment committee for the year now closed, consisting of Messrs. Emil Gerber, Ralph Modjeski and George P. Nichols, have contributed very largely, by their judicious and untiring efforts, to the instruction and entertainment of the members of this Society; therefore, be it

Resolved, That the thanks of this Society are tendered them for the able and faithful manner in which they have discharged their duties.

The meeting then adjourned to the banquet hall, where, after the banquet, the pleasure of the evening was greatly enhanced by the artistic rendering of selections from Bargiel and Mendelssohn by Mrs. Nettie R. Jones, piano; Mr. C. E. Schauffler, violin, and Mr. Day Williams, 'cello, under the direction of Mr. Schauffler, Assoc. M. W. S. E.

ANNUAL ADDRESS.

By Horace E. Horton, President.

Gentlemen of the Western Society of Engineers:

On occasions like this, it is quite the usual thing to magnify the engineer, to claim to him belongs credit for the rapid progress of civilization during the past century.

True it is, engineering began with the ability to convert heat into energy, and with this knowledge came the age of steam, the steamship and railway, followed by the telegraph; and now we use electricity as an agent; we invest heat, and in return, at any convenient point (which may be movable) receive from the electric current either power, heat or light.

The Engineer's works are more wonderful than the historic "Seven Wonders of the World." Surely we should be excused if we indulge in self-glorification.

In looking over the progress in mechanic arts, and what has been accomplished by the evolution of steam and electricity, it would seem as if the engineer of the future had little to do but to follow in the footsteps of his predecessors; however, when our attention is called to the fact that man has never yet been able to get useful energy of more than fifteen, and usually not more than five, per cent. of the equivalent energy of fuel employed, it is at once apparent that we have still opportunity for progress.

When the engineer has devised means whereby we may use the heat units of the coal in the earth, without the inconvenience of having to mine it, and get ninety-five per cent. of the equivalent energy instead of five per cent., then it may be accepted we have reached the limit of development, as far as evolving power from the carbon stored in the earth.

We also have with us flowing water, the tides and the heat of the sun,

and as a side issue a chance for conserving the energy of the winds as they blow. We may safely assume the engineer's opportunity in means to economize energy will not be exhausted in the nineteenth century.

In the movement of civilization, and with the elaboration of mechanical appliances in this age of steam and electricity, the engineer is being more fully recognized in the industries from year to year, as well as in public works and means of transportation.

Our attention is particularly called at this time to the large increase in the use of electricity for transferring energy, as well as conveying of power; further, that electric transmission in exceptional cases has superceeded the use of the steam locomotive on our trunk line railways.

Our attention is also called to the very marked tendency to use the gas engine, where the demands are for small units of power, or especially portable appliance, as illustrated in the motocycle contests, so recent in our city.

The greater works of the early engineers were canals, mostly of small cross-section, very useful in their way in reducing cost of transportation; however, the railway has clearly shown its superiority over the canal to meet most conditions. I think it will be generally accepted as a fact that there are locations where railroads can not serve the purpose of a canal; also that there are conditions where a canal can not serve the purpose of a railroad; that the locations where a railroad will best serve are met a thousands times to where the conditions demanding the building of a canal are met once. This superiority of the railroad on most lines has led many people to assert that the canal is too slow; however, the Suez canal, built where the physical conditions and volume of traffic justified the building, is a great success. We have not heard it suggested that a railroad would be prepared to compete. DeLesseps carried the Suez canal to success, but failed at Panama, because of the physical conditions.

Within a year a government commission has been appointed by the United States to report upon the feasibility of the Nicaragua project. This society has reason to be proud of the fact that the civilian member of said commission is one of us.

We have established a relation between heat, power and motion. The demand to be given an equivalent for investment, is arbitrary, whether the appeal is being made to the capitalist or to the government.

The co-efficient of friction of various methods of transportation are fairly well established.

We have been shown by experience that an artificial water way can only be maintained where there is an immense aggregation of traffic, and further, only where the physical conditions are very favorable; also, that such artificial water way can only be profitably employed in this age when constructed for vessels of the largest class.

The engineer discovers the lines of least resistance.

It is also the engineer's privilege, with the data in hand as outlined above, to develop a formula of general application that may be applied to any given route to determine its practicability.

Two water ways have recently been constructed in Europe of large proportions, one in the interests of the German empire for national and defensive purposes, the commercial use being only incidental; the other by the City of Manchester, England, for commercial use. The public press has been calling our attention to the failure of the Manchester canal, due to the fact that it is not paying operating expenses.

Viewed by the conditions suggested as necessary for a successful work, that is, immense concentration of traffic, and as the Manchester canal can only divide, in some small proportion, the tonnage of Liverpool, the fifth city in column of ship tonnage in the world, we question whether the enthusiasm of the builders may not have over-reached their judgment.

To come nearer home, we see the general government building the Hennepin canal across a portion of our own state. By the gauge we have outlined, we are safe in predicting the flat failure of this enterprise, if ever completed.

I have enlarged on this subject because of Chicago's great concern in this question of water ways.

With the completion of the drainage district work, a very considerable part has been done towards a water way of magnificent proportions to the Mississippi River, but we are confronted with the claim that the volume of traffic is not sufficient to make the undertaking a successful commercial one, while the argument on the other hand is, that the national question is all important and the work a necessity. It will cost much less than Germany has invested for a water way of very much less importance.

It is not my purpose at this time to attempt to prove either line of argument, and merely suggest that if some considerable portion of money frittered away each year on useless river improvements and such enterprises as the Hennepin canal, could be applied to the Des Plaines and Illinois River Valley it would in a few years develop a water way of magnificent proportions, one through which a large proportion of the vessels of our navy could be brought into the lakes, and, further, a large volume of traffic would surely follow.

While sentiment seems to be divided as to the advisability of expenditure on the Des Plaines and Illinois River line, there is clearly a belief among all the people all about and tributary to the great lakes that the one in a thousand routes for a canal of sufficient proportions to carry vessels of the largest class is from the lakes to the ocean, and in the direction that traffic has clearly indicated, as the line of least resistance, that is to New York, should be undertaken at once and canal forwarded to early completion. This feeling has become a force of proportions such as to cause the general government to move in so far as appointing a commission to consider and report on the question, and our society has again been honored by the appointment of one of its members on said commission. The magnitude of the enterprise, as outlined, is greater than any work ever proposed and carried to completion by man. However, the vital interests involved are so great that nowhere else on earth can so much energy be profitably invested to facilitate transportation. The demands for this work are national, because of the economic advantages as well as a means of defense.

Consider for a moment the volume of traffic tributary. Chicago is fourth in size of seaports on earth. Chicago's tonnage is only one-seventh of the tonnage of the lakes, and we can readily comprehend the force of the movement toward this magnificent engineering project.

We hope the government will undertake the work, which will surely be a fitting culmination of engineering progress of the nineteenth century, and to our society will come reflected glory through its various members so closely identified in the inception of the work.

In looking back over the year 1895 and what it has brought to the Western Society of Engineers, most important is our withdrawal from the Association of Engineering Societies. I see no reason to doubt the change will be as beneficial as its most enthusiastic supporters have predicted; the outlook is very encouraging.

The society is under great obligation to the Armour Institute of Technology, its president and faculty, for the use of its rooms and appliance, where we have had the advantage of stereopticon views, more fully illustrating many valuable papers there presented.

We have had several outings, as well as profitable excursions, due to the energetic efforts of our entertainment committee.

We have moved our home from the Lakeside Building into the very pleasant and commodious rooms in the Monadnock.

We have increased in membership.

We have increased our library, and, more important, have it in shape so it may be used.

We have the comfort and satisfaction of knowing we have lived within our current income without the necessity of asking alms.

ADDRESS.

By John F. Wallace, President-Elect.

Gentlemen of the Western Society of Engineers, I thank you for the honor that has been conferred upon me. How well I will be able to bear the responsibilities you have placed upon me I do not know. Time alone will tell.

In looking over the programme tonight I find no mention made of an address by the incoming President, and in our constitution there is no clause making it his duty; but I do find it is obligatory on the retiring President. I might therefore take advantage of the technical requirements of our constitution and say nothing. As you well know, I am not gifted with the fluent and silvery tongue of a Cooley or the flowery speech of a Randolph; but as there are probably more of you here tonight than there will be at any subsequent meeting of the association during my term of office, I feel it incumbent upon me to take advantage of your presence and make a few remarks in reference to our profession and what we should try to do during the coming year.

The status of engineers in this country is in our own hands, and it is only by paying strict attention along the lines of personal improvement that we can improve the character and dignity of the profession. After all, we are governed by selfish motives, and the real object of our Society is the advancement of the interests of the individual members thereof. To accomplish this, however, it is necessary for us to have an organization, and the affairs of this world are so wisely ordered that we cannot work for our own personal interests or for the advancement of our profession without materially benefitting the world at large—and it is right that it should be so.

There are various lines upon which our Society work can be developed. First, the enlargement of our library, which can be accomplished through contributions by members of books, photographs, drawings, etc.; by public documents systematically requested from the proper authorities; by exchanges in return for Society publications, etc.

With reference to the systematic gathering of public documents and state reports: The statement was made some time since by Mr. Morgan, one of our members, that the Society should incorporate its library, which can be done at a nominal cost. This would result in our being placed upon the list of state and public institutions, and being furnished in a systematic manner with all state reports. Care should be taken, however, that the enlargement of our library does not result in the accumulation of duplicates and worthless matter. The material should be carefully selected and the duties of the librarian performed in a systematic manner, in order that the books and papers so secured may be easily available for reference.

The papers read before the Society form one of the most important lines of society work. It is not only a privilege, but a duty, of which all members of the Society should avail themselves. The young members frequently, through modesty, hesitate to present papers; the middle-aged and active members claim they have not the time; and our older members, looking on all things as vanity, and feeling that their long years of work and study have simply taught them how little we actually know, refrain from giving us the results of their ripe experience. There is not a member of this Society who cannot give us some information concerning the works in which he has been engaged or views of his own that would be of value.

In addition to stated papers, we should also have discussions on special subjects. When great public questions arise involving engineering problems, they should receive attention from the Society. A united effort should be made to aid the publication committee in every possible way.

In addition to our development in Society work, attention should be paid to the individual, as it is the aggregation of individuals that forms

our Society. While all engineers should have a good technical education, they should also have a broader education along the lines of general knowledge, and every effort should be made to improve and develop the personal unit. More care should be given to personal dress and address. While these may be small matters, they still frequently contribute to success, and they are points too often neglected by engineers. During the Columbian Exposition the engineers of Chicago gave a reception to the American Society of Civil Engineers, which was supposed to be a dress affair; yet at this reception a large number of our members appeared in ordinary business suits. If we desire to stand high in the opinion of the world and be considered a learned profession, we should pay some attention to the rules of social life. A learned man should neglect nothing, and should have a regard for all laws and forces, whether spiritual, material or social.

Again, no matter what the position of the individual engineer, he should cultivate discipline, giving prompt obedience and respect to the instructions of his superiors, and demanding the same prompt obedience and respect from those reporting to him.

Loyalty should also be cultivated. While an engineer may respectfully carry out the directions given him, he should go beyond this and should give his chief, or the officer to whom he reports, that loyal service which sweetens the relations between the chief and his assistant.

The individual engineer should be methodical, as it is only by method in this busy age that our duties can be satisfactorily performed.

A broad knowledge of men and affairs should be sought for, in order that we may keep thoroughly in touch with the rapid progress of events. It has been said that engineers should not only have the power to construct public works, but they should also be able to design them. It seems to me the requirements of a perfect engineer should include a great deal more than this; and that it is not enough to be able to design and execute, but that the engineer should also be able to conceive works of a public nature; and that the power to conceive, design and execute should not be confined to the technical side, but should also take in the broader qualities of diplomacy in order that the engineer may reach the highest stage of perfection and success. Engineers frequently measure themselves and each other by their mathematical ability, or by the neatness and clearness of the details of the plans they design. While these technical accomplishments are highly desirable, they are only minor factors in the make-up of the successful engineer, and hold the same relation to engineering science that what are known as "tactics" do to military science. No matter how good a tactician a general may be, if he is not well versed in the higher principles of strategy his knowledge of tactics goes for little. It is the same in engineering. While we should improve and cultivate our technical knowledge, we should not forget that the highest success depends upon the knowledge of business diplomacy and all those things that go to form the strategy of business.

In this connection, we should not lose sight of the fact that the measure of success in human affairs is, after all, the dollar. It is not enough that we may be able to design a canal, but we should be able to carefully consider the functions it will be called upon to perform, and the material return it should make either to its promoters or the public at large. It is not enough that an engineer should be able to design and construct a railroad; it is essential that the design and construction should be economical, and the line so located and constructed as to enable the greatest amount of tonnage to be carried at the least cost per mile; also so located in regard to business requirements as to yield a traffic that would be remunerative to the capital invested. No matter how firmly the masonry constructed by an engineer may stand, no matter how scientific may be the construction of his bridges, no matter how low the grades or easy the curves on the railroad he has built—if it will not stand the test of the dollar, it is in a measure a failure.

Only by strict attention to the factors noted above can we achieve the highest success, and through these factors raise the status of our profes-

sion; which, I am sorry to say, is not as favorably looked upon by the public as it should be. Across the water the professions rank: Engineering, the Church, Law, Medicine. On this side of the water the order is: Law, the Church, Medicine, Engineering; with the Engineering profession on the border line, and looked on more as a trade or an art than as a profession.

In reference to actual work, we are apparently on the verge of more active times, which we hope may bring additional work to the members of our profession. Six years ago this Society took up the question of the general rapid transit problem in Chicago. Since that time a large part of the Illinois Central Railroad has been elevated, as well as the Lake Shore, Rock Island and Northwestern tracks; and evidently the elevation of all the steam railroad tracks in Chicago will soon follow. Other problems present themselves, one of which will be the eventual necessity of the separation of the different forms of street traffic. The demands for the highest engineering talent on our railroads have become yearly more urgent, and our services in this direction are becoming more appreciated. Some years ago a committee of stockholders investigated the condition of the Illinois Central Railroad, and decided that as the road was finished and the construction account closed, the engineering department could be dispensed with. Today that department is considered one of the most important on the road, and has the supervision of the expenditure of millions of dollars every year. The same condition of things applies practically to all our large railroad corporations. The development of the country is causing an increased demand for better railroad facilities—double tracks, heavier bridges, better roadbed, scientific arrangement of yards, shops, station buildings, warehouses, docks and wharves, elimination of grade crossings, both as to streets, highways and railroads; interlocking and block signals; the application of electric power—all these things present fields for the employment of Engineers of the highest order in all departments of engineering.

It is the hope of your President that the members of the Western Society may come in for their full share of the advantages to be reaped by the engineering profession.

After speeches by Hon. D. P. Phelps, Prof. Carman and Prof. Roney, Dean of the Armour Institute, the President called upon Mr. Reynolds, chairman of the Publication Committee, who reported as follows:

To the Western Society of Engineers.

Gentlemen: The Publication Committee beg to report as follows: The first meeting of the Committee was held December 1st, when it was decided to issue the Journal for 1896 bi-monthly; each number to contain about 96 pages of text. There will be four principal divisions of the reading matter, viz.:

Papers read before the Society and discussions upon same,
Topical discussions,
Abstracts from Foreign and American transactions and periodicals,
Proceedings of the Society.

The first number of the Journal will be issued about the 25th of this month. The subscription price has been fixed at $2.00 per volume of six issues. There will be printed three thousand copies of the first number; about five hundred of these will be required for the members of the Society; from three to four hundred for exchanges; about two hundred for reserve, to be held for new members; the additional copies will be used in an effort to obtain the largest possible number of subscribers.

We beg to give you further information in detail as follows:

PAPERS AND DISCUSSIONS.—The Committee have arranged that all papers presented to the Society will be printed, and advance copies furnished to all of the members, thus giving every member ample time to thoroughly consider the subject of the paper and discuss the same either by being present at the meeting set for the discussion, or by sending a

written discussion on the subject. We expect that this will lead to very much more general discussion, and will moreover encourage members to present papers to the Society. It will also lead to a very much more thorough discussion of papers than it has been possible to obtain in the past. The Committee count upon the co-operation and assistance of each member of the Society in making the Journal a complete success. We ask that each member shall, whenever opportunity occurs or he has information of general interest, contribute a paper to the Society, and that he shall also take part in the discussion of other papers, especially when the subject is in his particular line of work. All papers will be illustrated as fully as may be necessary. The Committee can assure all members that every paper will receive the most careful consideration, and those which it may be decided to print in the Journal will be promptly printed and submitted to the Society. If it is found necessary, the number of pages proposed for each number of the Journal will be increased, and no expense will be spared in giving papers read before the Society the fullest publicity and in illustrating them in the best possible manner. As the object of the Society is to embrace all branches of the profession, we will endeavor to secure papers of interest to each branch, thus making it an inducement for those branches but poorly represented numerically in the Society at present to join and feel that it is a Society for not one, but all branches of the profession.

TOPICAL DISCUSSIONS.—We propose to take up one or more subjects of general interest to the profession in each number. By means of these discussions we not only expect to get valuable practical information from persons not members of the Society as well as from members, but we also expect to attract the attention of producers, manufacturers, dealers and allied interests, and in fact all persons interested in the subject under discussion. If by these discussions we can attract the attention of these different interests, we not only make the Society valuable to its members, but also to the public, and when we do this, we can look for and will receive the support of the public in such a substantial manner as to make the profession and the Society of still greater value, not only to the members, but also to the public at large. In selecting subjects for these topical discussions the Committee will not confine themselves to any one branch of the profession, but will select subjects from time to time which will bring out information of value to all branches of the profession.

ABSTRACTS.—The Committee hope to be able to print in each number of the Journal abstracts from the transactions of Foreign and American Engineering Societies, and also from Technical Journals, which will be of value to the members. These abstracts will be made from publications which may be received for the library of the Society, so that if any members desire to consult the original paper, it can always be found on file in the library. The Committee believe that these abstracts will prove of much interest and that the members will be able to keep in touch with current engineering work and literature both in this country and abroad. Your Committee count upon the assistance of all of the members in this department of the work. Each abstract will be marked with the initials of the member who makes the abstract. The value of this part of your Journal will depend very largely upon the interest taken in it by the members individually, and also as to whether a sufficient number of the members of the Society will volunteer to make abstracts for the different numbers of the Journal. Your Committee feel that no portion of your publications can have as great an influence in creating an interest in the Society, among engineers who are not members, as the "topical discussions" and the "abstracts."

RESULTS.—Your Committee are pleased to report that there is an abundance of material in hand for the first number of the Journal, and judging from the present outlook, there will be very little trouble in securing valuable and interesting material for each succeeding number. It is more than probable that the first number of the Journal will contain considerably more than one hundred pages of reading matter.

Bids were received from a number of publishing houses upon a Journal

containing 96 pages of reading matter and 16 pages of advertising. The lowest bid, which with your authority was accepted, was $167.00 for the first one thousand copies, and $44.00 per thousand for additional copies. This price did not cover illustrations or tabular matter. We cannot give an exact estimate of the cost of the Journal, but judging from the data we have in hand at the present time, we anticipate that the total cost of the six numbers will be about $2,000.00.

REVENUE.—We have contracts for 19 pages of advertising, aggregating $1,776.00, for 1896. We feel confident that the total amount received from advertising for the six numbers of 1896 will be about $2,200.00. A further source of revenue will be from the sales of the Journal and reprints. We believe that with very little effort five hundred subscribers, not members of the Society, can be secured. This will give us an additional revenue of $1,000.00. We are confident that with the revenue from advertising and subscriptions we will be able to publish the Journal in a manner which will do credit to the Society; that we will not be obliged to ask the Society for one cent toward the publication, and that practically the Journal will be published without any expense to the Society. In order that this result may be obtained, we expect the earnest co-operation of every member of the Society, and we count upon each member securing at least one subscription to the Journal.

Yours respectfully,
The Publication Committee,
JAMES J. REYNOLDS, Chairman.
THOS. T. JOHNSTON.
CHAS. E. BILLIN.

Jan. 7th, 1896.

Mr. Reynolds—I might add, Mr. President, that the first number of the Journal will contain an article on Railways of the Orient, by Mr. Clement F. Street; Notes on Dry Docks, by Mr. A. V. Powell; papers by Mr. T. T. Johnston and Mr. L. E. Cooley on waterways to the sea; hydraulic cement and its uses will be discussed by several members, etc.

We hope the members of this Society will show their appreciation of the generous support that the advertisers have given us by consulting the advertisements for their wants, as we are sure they will find what we expect to make of the Journal, and that is, the very best that can be had. (Applause.)

It was moved and seconded that a vote of thanks be extended to the Publication Committee. Carried.

It was moved and seconded that the report of progress of the Publication Committee be printed in our regular proceedings. Carried.

(MUSIC.)

The Chair then introduced Mr. Mordecai, of the Cleveland Society of Engineers.

Mr. Mordecai—Mr. President and Gentlemen of the Western Society: I come here to give the greeting and well wishes of one of the older clubs of the Association of Engineering Societies, and I can assure you, that after you get through staggering along alone, and when you get to feeling uncomfortable and wanting company, that not one of the clubs will give you a warmer welcome back than the Civil Engineers' Club of Cleveland, and I hope it won't be very long, notwithstanding Mr. Reynolds' report. We have a city there on the lakes, a sister city which is not as large as Chicago, and if the engineering skill of the members of the club, and the proverbial energy of Chicago will not destroy our harbor, I think after a while we will have quite a metropolitan place. A thought struck me in listening to your president, and that is, that the engineers always appear to the public through agents. Take for instance the thousands of people that travel across the Brooklyn bridge every day; they all know the doctor that they consulted, because they were brought in personal contact with him; they

all know the lawyer that they consulted in their last lawsuit; they know the clergyman that they heard last Sunday, but very few of them know the able and accomplished gentlemen to whose skill and ability they owe their safe and very quick travel every morning, and that I think is one of the troubles of our profession, that we are not known more as individuals, and it is for gatherings such as this to show even to ourselves what right royal good fellows we are, and what able and accomplished men we are. I thank you, gentlemen, for your kindness, and the great pleasure of my being here.

Mr. Wallace—I think before Mr. Schauffler and his friends leave the room, that we should extend to them a vote of thanks for their entertainment. (Great applause.) The expression of the Society is in itself a vote, and we will consider Mr. Schauffler and his friends have the unanimous thanks of the members present.

Speaking about loyalty, the loyalty of assistants to a chief, there is a still higher kind of loyalty that we should cultivate, and that is loyalty towards brother members of our profession, and that we should extend to them our support and our sympathy when they are under fire. Near the limits of the city of Chicago is now being carried on one of the greatest works of the age. One of the remarkable things about that work is that it has so far cost less than the estimates. There has never been a suspicion of jobbery or corruption that has been attached to either the trustees that control it or the engineer or his assistants that have charge of the engineering features. That the chief engineer should be under fire, and corrupt influences should be brought to bear to displace him, and place another in his stead who might be more pliable, it seems to me, calls for an expression of our indignation, and the support and sympathy of every member of the Western Society of Engineers should be extended to this chief. I refer to Mr. Isham Randolph. (Long-continued applause.)

The Society would be pleased to hear a few words from Mr. Randolph. We do not wish to forget that he is one of our members.

Mr. Randolph—Mr. President and members of the Western Society of Engineers and assembled guests: If I had not been invited to speak here tonight, I should for the first time in my life have asked the privilege of addressing an audience, and it is this audience that I want to address. The good-will and the commendation of men whom I esteem is dear to me. Their praise is like precious incense to my heart, and I want to thank you for the way in which, as individuals and as a Society, you have rendered me aid in this, my time of need. I want to thank you for a resolution which was passed by this Society on the 6th of November, expressing your approbation of my work. I shall file that resolution away for my boys to read in years to come, when they look over their father's career for evidences of which they may be proud. But, my friends, much as I love human praise, I would not wear a laurel which belongs to another's brow. You have spoken well of my work, but you must not forget that when this great work was in its incipiency, my thought was not in touch with it. When it began to take form and shape, I lent it no aid. When the great forces which brought it to the condition in which it is now were put in motion, I was a doubting Thomas, and did not think that the resources of this people were equal to such a work. Many surprises come to us in the course of our lives, such have often come to me, but never was there a greater surprise than when on the 7th of June, 1892, I was invited to take charge of this great work. I took it in diffidence of my own powers. I came to the work a stranger to it and to the men with whom I had to work. I had to study both the work and the men who were to help me do it. I knew scarcely more than their names, and yet I had to trust them, and I did it unreservedly, and I made no mistake. I was among men who were first loyal to their duty, and second, loyal to the chief whom fortune had placed over them. But for these men and their loyalty, I could not have stood before you here tonight with a feeling of pride in the work which has been accomplished. The man who is my right hand you have honored with your votes, and he is the right hand now of your honored president. (Applause.) Yonder where the queen of the world's great lakes spills its surplus waters in foam

and torrent through the rocky channel of the Soo, stands a great engineering work which takes from that waste of waters a noble flood and makes it lift and lower a mighty commerce from the level of Lake Huron to Lake Superior. That work is a man's monument, the monument of a soldier engineer who lives now but in the evidences of his efforts which he has left behind him. General Poe said of Johnston's treatise on the levels of the Great Lakes, that it was the ablest disquisition on that subject which he had ever seen. I have often heard the work which comes from his draughting office praised for its excellence. The plans and maps bear my name as chief engineer, but the work is done under the supervision of the quiet, able, unassuming man, Edgar Willliam. At one time there were upon our muster roll seven assistant engineers. These men were trained in schools, and from the schools they passed into that grander school of experience, where from year to year they gather knowledge, and adding knowledge to experience, they become masters of the profession which they have chosen. Harrison, Alexander, Schnaebel, Ward, Kastl, still answer to the muster roll and do yeoman service to the district. Schraeder has gone to the West Park Board, and Miller to the Metropolitan Board Supply Commission of Boston, and they prove each, that when patient, able servants are needed, that they may be drawn from the supply of the Sanitary District of Chicago. I could go on down through the list, naming men who will climb the ladder of distinction and make their mark in the future of our profession. But suffice it to say that I am proud of the men who work with me and they are worthy of it.

Perhaps you would like to know something of the present status of this work. At this time 77.6 per cent of the main channel work is completed, 20,416,000 cubic yards of glacial drift lie heaped upon the spoil banks, and that rocky ridge which we call the cantilever range has in it now about 10,500,000 yards of solid rock taken from the canon which forms the channel. Ninety-nine thousand five hundred yards of masonry has been completed. From the middle of Section 8 to the middle of Section 14 the noblest channel which man has ever built is completed and waits for that mighty flow which, like Tennyson's Brook, but greater, shall go on forever and forever. My friends, I know not whether I shall be permitted to order the opening of the flood gates which shall bear the tribute of Lake Michigan to the Gulf of Mexico and bring deliverance to this city from the evils which we well know but may not name. But when that time shall come, whether I am with the district or simply an onlooker, I shall rejoice in the success of this enterprise; but, whatever comes, I shall look to this society and feel grateful to it for the good will and the kindness of the men whom I look upon as my brothers. I thank you. (Great applause.)

The chair then called upon Capt. Robt. W. Hunt, who spoke as follows:

Mr. Hunt—Mr. President, it was with considerable embarrassment after your remarks, that I remained near the head of the table. In fact I found, or at least thought to myself, that I was out of place there among the gray and reverend and bald-headed people, and naturally drifted to where I belonged, among the boys. But when I got to that end of the table, I found that I again had made a mistake, because I was close to either a bear trap dam, or the man who says he has the contract to build, as he expressed it, a dam bear trap structure, so I thought I was not safe there and drifted back again.

You embarrassed me, sir, when you pointed out to the other members of our profession, to us who have not had the experience which has been granted to you, the necessity for dress. How do you think I have felt since those remarks? Now that ancient friend of yours who came pretty near having his pants in his boot legs by the way, you made a mistake, I have a knowledge that he did not have boots on at all; they were just plain, honest moccasins. You know different ideas as to full dress prevail. The engineers of the various nations do not all dress alike. Why, surely you were down on the Midway, and saw some most expert engineers that were not clothed, when they first arrived upon the premises, in the habiliments that you perhaps would think necessary for them to have worn here this

evening. Still, they were fine looking people, and some of them had not a line that any engineer should object to gazing upon. It seems to be my fate, Mr. President, to antagonize other professions. Perhaps it is because lately I have been trying to make a living by finding fault with what other people do. A year ago a good lawyer friend of mine stated that engineers had a way of asking for quite as much compensation as belonged to them. He was a past judge and enjoying the profitable profession of the law. You may remember I suggested to him that if we had not learned how to charge that which was sufficient for our services, it certainly would be because we had not followed our brothers of his own profession.

Now do you know, Mr. Chairman, I think there are a lot of tired people here to-night that want to go home, and they undoubtedly are saying that if you had not asked me to speak, and if I had held my jaw shut a little while longer, they would be on their way toward bed, and that reminds me, a dear friend of mine had a personal incident happen to him a few weeks ago that recalled this story to him and he told it to me:

In a western city which had a river running past it there was upon one occasion a corpse found. It was taken to the morgue and the papers reported the fact. It so happened that some little time before a worthy gentleman of the city had disappeared. His widow was disconsolate, she had advertised in all directions and employed detectives to try to find this missing man. She saw this statement in the paper and went to the morgue. To her surprise, and sorrow, too, of course, she recognized lying upon the marble slab the remains of her lost husband. Of course she was overcome with grief, but still the dear affectionate wife had presence of mind enough to tell the keeper of the morgue to send for the best undertaker in town. He came down, pencil and note book in hand, and between her sobs, she said, "Now this must be a fine funeral." He said, "Yes, ma'am, your orders go." "Do not spare expense," she said. "They shall not be spared. Casket?" "The best casket you have in the house." That was noted. "Flowers?" "Flowers! Oh, let there be many flowers." Well, in his own commercial mind there was about $500 profit in that funeral. But just as he was assuring the weeping woman that everything should be to her desire, the lower jaw of the corpse dropped and she discovered that he had false teeth. "Why!" she says, "that is not my husband; he did not have false teeth; this is all off." She went out, the man with the $500 gone looked at the corpse, and said, "You go to the potter's field. D—— you, if you had kept your mouth shut five minutes longer, you would have had a fine funeral."

Adjourned.

CONTRIBUTIONS TO THE LIBRARY.

CONTRIBUTIONS to the Library will be acknowledged in each number of the Journal. We will appreciate receiving copies of professional books, pamphlets, unbound periodicals, maps, plans or photographs.

At present the Society has a library of over 2,000 volumes, besides pamphlets, drawings, etc., and desires to make this the nucleus of a central technical library of reference. The books will be made accessible, under liberal rules, to all parties interested in Engineering and allied subjects.

Contributions coming within the scope of the library, will be inscribed with the name of the donor and will receive proper care. Duplicates will be disposed of by exchange or sale. We need several special numbers of periodicals, in order to complete our files, and we have many duplicates which we will be glad to exchange.

LIBRARY COMMITTEE.

ERRATA.

VOL. I, NO. 1.

Page 46. Equation (1) should read: "$w\,h = \frac{w}{2g}\,(v^2 - v_1{}^2) + f\,(R)$."

Page 46. Paragraph at Bottom of page should read: Particular attention is called to the expression $f^1\,(R)$. It will be noticed in the discussions above referred to, that this term has been neglected. This fact has led to the deduction that $H - h$ in the Fig. 28 $= \frac{2}{3}\,H$. The particular experiment in hand shows $H - h = 0.587 - 0.274 = 0.313 = 0.533\,H$. And the Cape Fear River case shows $H - h = 0.5 = \frac{2}{5}\,H$. Perhaps these discrepancies may be reconciled by a proper consideration of the "friction not considered," or the value of $f^1\,(R)$.

Page 49. Second paragraph should read: The large values $s_2 - s$ for $f^1(R)$ are remarkable. They form about two-thirds of the total head lost to a. They are to a certain extent, however, consistent with the fact that $H - h = 0.533\,H$ instead of $\frac{2}{3}\,H$, as called for by the formulæ used in previous discussions of the subject.

Page 49. Equation at center of page should be: $Q = c\,h^{3/2}$.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

Vol. I. APRIL, 1896. No. 2.

V.

MECHANICAL METHODS OF ROCK EXCAVATION USED ON THE CHICAGO MAIN DRAINAGE CHANNEL.

With Particular Reference to Cost of Work.

By W. G. Potter, C. E., M. W. S. E.

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Canal building, like all other branches of engineering, has within the last half century made many forward steps. Where once the pick and shovel were the implements of excavation, we now have the powerful steam shovel and the hydraulic dredge; where formerly all drilling was done by hand, we now use the steam or compressed air drill; where, in days past, all blasting was done by powder and all removing of material by cart and wagon or wheelbarrow, we now use dynamite and huge steam conveyors.

It is the purpose of this paper to treat of the methods, first, of excavation on a few of the recent foreign canals; and second, of the rock excavation on the Chicago Main Drainage Channel.

It was the intention of the writer to devote some space to earth excavation also, but lack of reliable data has rendered such a study unprofitable. The little earth work that is being done on the Lemont Division, where the writer is located, would permit of no general conclusions; therefore the paper will be devoted entirely to rock excavation and the methods employed thereon.

The following is a synopsis of the paper:

PART I.—FOREIGN CANALS.

Suez Canal.
Panama Canal.
Manchester Ship Canal.

PART II.—CHICAGO MAIN DRAINAGE CHANNEL.

General Information.
Channeling.
Drilling.
Exploding.
Conveying by
  Car Hoists,
  Hulett Conveyor,
  Hulett Derrick,
  Hulett Cantilever,
  Double Derricks,
  Cableway,
  Cantilever Crane.
Comparison of Cost and Efficiency.
Conclusion.

THE SUEZ CANAL.

First in importance, commercially, among recent canals, and first in time of completion, is the Suez. It has from an engineering standpoint no remarkable features except in being the pioneer of modern canals, however its effect in stimulating canal engineering has been great.

The total length of the Suez Canal is $99\frac{1}{2}$ miles, with about 66 miles of actual excavation. For about $11\frac{1}{2}$ miles the excavation reaches a depth of 50 feet, and the deepest point is 102 feet. The remaining surface is less than 10 feet above sea level.

The material excavated, amounting altogether to eighty million (80,000,000) cubic yards, was nearly all sand or alluvial deposit. The additional material consisted of a soft gypsum, most of which required no blasting.

Construction was begun by the Khedive of Egypt. Thirty thousand men, mostly natives, were employed for several years, making but little progress. After allowing the work to be almost abandoned, the Khedive died and the work was resumed under the guidance of Ferdinand de Lesseps and a French company. By them the method of construction was entirely changed. Sixty immense dredges, each costing one hundred thousand (100,000) dollars, were put to work.

Submarine stamps or crushers were also used to crush the gypsum and prepare it for the dredges.

The construction by such means was completed in 1869.

The essential point in the Suez excavation was the abandonment of the old method of man power, and adoption of steam power and machines as the principal means of work. Since that day the number of men used in excavation has continually decreased, and mechanical methods have been advanced and adapted for use in all large undertakings.

AUTHORITIES.

Mr. J. D. Estabrook, Journal of Assn. of Eng. Societies.
Mr. O. B. Gunn, Journal of Assn. of Eng. Societies.

THE PANAMA CANAL.

The Panama Canal was originally intended for a sea level canal, construction being begun by submarine dredges at both ends and by excavators and land dredges in the principal cuts.

It was to have a depth in earth of 26 feet of water and $29\frac{1}{2}$ feet in rock, and a bottom width of 72 feet in earth and $78\frac{3}{4}$ feet in rock. Estimates made the excavation 122,377,000 cubic yards of earth and 33,368,000 cubic yards of rock.

LAND EXCAVATION.

The drilling in rock excavation was done mostly by ordinary hand or churn drills by common laborers. Drills were from 6 to 15 feet long and the price was from 6 to 10 cents per foot for holes less than 8 feet deep and from 10 to 15 cents for those deeper, according to material.

This price also includes exploding, the powder being furnished by the contractor.

Of machine drills only one was used to any extent.

The Ingersoll Rock Drill, such as is used on the Chicago Drainage Canal, was introduced and thrown aside because of lack of skilled drill men.

The apparatus most commonly used, consisted of a platform car, on wheels of five-foot gauge, to the side of which was attached a frame supporting four drills, three feet apart.

By means of an engine on the car a circular or boring motion was given the drills through a shaft, and by this the holes were bored to the required depth. Then the drills were pulled up, the car moved on and four more holes were bored. When the ground to be blasted was all drilled, the car was moved back out of the way, the track pulled up and the shot fired. This method was very costly, however, on account of the necessary grading and track laying and relaying.

Besides blasting in drilled holes the Panama Canal is almost unique for blasting in large masses. Pits 3 feet square were dug 30 feet deep, and from these lateral chambers 3 feet square by 6 or 7 feet long were dug in both directions. Then these chambers were filled with powder and dynamite and exploded.

The principal machine for rock excavation was the steam crane, of which many were used. They were used to lift buckets of from one-half to one cubic metre load from the ground to cars on which the material was removed.

The machine methods for excavating earth were of four different types. The "down digger" French excavator was probably first. This is a heavy endless chain and bucket machine, a more detailed description of which will be given under the Manchester Canal. With care this machine could excavate from 1,200 to 1,800 cubic yards per day, at a cost of one cent to one and one-half cents per cubic yard loaded on cars at the excavator.

Second, the "up digger" French machine, the buckets of which were turned up in cutting instead of down as in the first type. Both of these machines were heavy and could not be used in wet weather because of the caving of the soft banks.

Third, the Osgood shovel, a two-yard dipper dredge, with capacity of 2,000 cubic yards in 10 hours.

All of these methods were for loading cars.

The fourth method in use was for dumping at the side of the excavation and consisted of the up digger excavator, with an endless belt conveying attachment. Material discharged from the excavator buckets, falling on this belt, was carried out 500 feet and up 30 feet above ground and was then dumped. On account of the grade becoming too steep, this method could only be used on the first lift, or the first 30 feet of excavation.

SUBMARINE EXCAVATION.

Submarine drilling and blasting was done by a unique and efficient method. It consisted of an anchored scow, containing through its center an open space of about 15 by 20 feet, over which ran a traveler containing four drills. These drills, each one of which was in a water tight iron pipe, bored their holes to the required depth. These holes were then loaded for firing with wires in place. Then the traveler was moved forward over the open space and four more holes were drilled. After all the holes were drilled and loaded, anchor was pulled up, the boat removed from danger and the blast fired by electricity.

Excavation under water was done mostly by dredges similar to land excavators or by hydraulic dredges, which conveyed the material outside the canal limits by means of pipe lines.

AUTHORITIES.

J. D. Estabrook, Journal of Assn. of Eng. Societies.
O. B. Gunn, Journal of Assn. of Eng. Societies.
W. P. Williams, Transactions of A. S. C. E.

THE MANCHESTER CANAL.

The Manchester Ship Canal, the largest in England, is the best example of completed canal engineering the world has yet seen. It is $35\frac{1}{2}$ miles long, 26 feet low water depth, and 120 feet minimum bottom width.

It differs from the Chicago Drainage Canal greatly, both in material and methods of excavation. The total amount of material removed was about 53,000,000 cubic yards, 12,000,000 cubic yards being sandstone rock. Of the total excavation about 3,500,000 cubic yards were removed by dredges, and the rest by land excavators.

Construction was begun in November, 1887, and completed in a little over six years. The rate per month varied between 750,000 and 1,250,000 cubic yards, and at no time were more than 1,600 men employed.

The excavating machines were of three general classes, steam dipper excavator or navvy, the bucket and endless chain machine, and the steam crane.

Of the first type nearly a hundred were in use, 58 being of one make. This, the Ruston & Proctor steam navvy, is a very heavy dipper excavator, weighing from 32 to 36 tons, and was used for earth and soft sandstone. Its buckets were of one and one-half to two and one-fourth cubic yard capacity. One thousand one hundred cubic yards have been removed by this machine in a day of 10 hours and a fair average is 600 to 700 cubic yards at a cost of little over one cent per cubic yard.

Of the second type of excavator there were seven in use, four "Frenchmen" and three "German."

The principle involved is the same as that of the ordinary bucket dredge. It consists of an endless chain running on a movable arm. To this chain is attached a number of buckets in which the excavated material is lifted. In passing over the inner and upper end of the arm, the bucket dumps its load and returns for another. There are two methods of running these buckets, one the "down digger," and the other the "up digger," the difference lying in the direction in which the bucket is moving when in the act of cutting or excavating its load.

The principal difference between the German and the French machines is in the method of dumping. In the French, the buckets deliver their loads over a chute into cars on an adjacent track. The cars are moved into position by a locomotive.

The German machine has a much wider base and the cars pass under it. The dirt is dumped through a hopper so arranged that dumping is not interrupted when the cars are not immediately under it. No extra locomotive is necessary for placing the cars in position, as the forward movement of the excavator is enough to fill the cars without delay.

The output of the German excavator, according to a paper by Mr. E. Leader Williams, Chief Engineer of the Canal, was about 1,400 cubic yards per day, at an expense of about one cent per yard, or three and one-half cents including the pit force for dirt loaded on cars. Its first cost is about twelve thousand dollars ($12,000). The best day's performance was 2,400 cubic yards.

The French machine averaged about 1,500 cubic yards per day, at a cost of nine-tenths cents per cubic yard. Its highest run was 2,250 cubic yards in one day.

While these machines have very high outputs they can only be used in places where the material is soft, and yet where the foundation for the track is hard enough to sustain a heavy load. For this reason, and for the reason that boulders, stumps and any hard material would suffice to stop them, their use is limited.

The last type of machine in use on the Manchester that will be mentioned here is the steam crane.

These were generally of 10-ton capacity and were used in transferring blasted material in loaded skips or buckets to the cars.

Thus we see that while introducing no distinctly new method of excavation, the Manchester stands foremost in rapidity of construction. It is worthy of note that the entire contract was given to one man, and worked by him successfully until his death, which occurred three years before the completion of the canal.

AUTHORITIES.

Mr. E. Leader Williams, Chief Engineer, M. S. C.
Mr. Nicholas P. Gedye, C. E., London.
"Engineering," of London.

PART II.—CHICAGO MAIN DRAINAGE CHANNEL.

GENERAL INFORMATION.

The rock to be excavated consists of about 12,071,668 cubic yards of limestone of the Niagara period. Starting from below grade on Section 1 (see map, Fig. 49), the rock gradually rises for a distance of about 6½ miles until, on Section 7, it reaches the natural surface. It practically forms the natural surface for about 7½ miles, from Sections 7 to 15. The deepest cut is about 38 feet.

The rock rapidly grows harder as the excavation increases in depth, the third lift being almost twice as hard to channel and drill as the surface lift. It also differs in structure in places. One kind, locally called the "tame" rock, splits easily in layers and is also a dimension stone, while the other, the "wild" rock, splits irregularly or not at all. The latter costs more for excavation in all ways. The strata are generally horizontal, and in no place is the dip enough to seriously affect the cost of excavation.

The channel, Fig. 50. in rock is 160 feet wide on the bottom, with practically vertical sides. It has a grade of one foot in 20,000. In places where the rock is more than 15 feet above grade, more than one cut becomes necessary, and in this case an offset of 6 inches is made on each side of the channel, as is shown in cross-section sketch, under "Channeling."

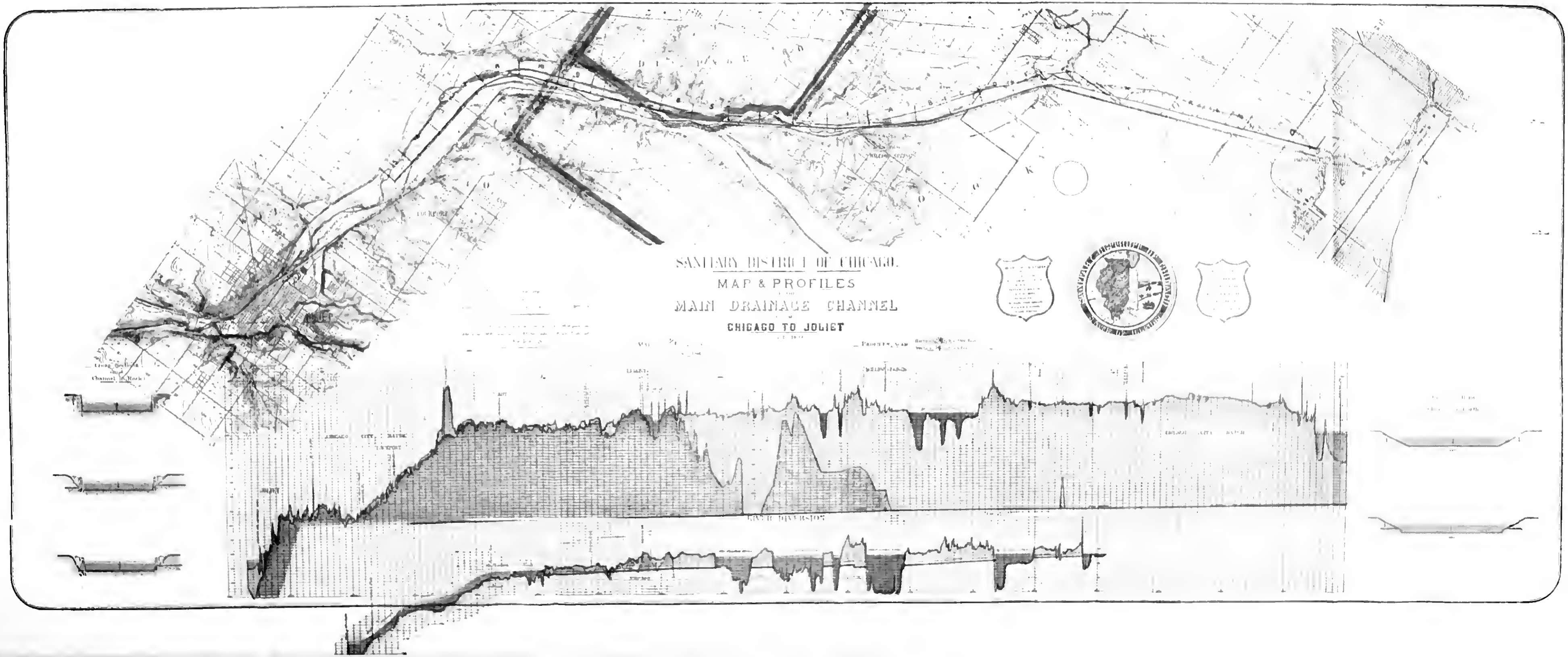
All material is wasted on the sides of the channel, a natural berm of 50 feet being retained between the excavation and the toe of the spoil bank.

The general method of excavation is to take out the first cut with wagons and carts or with car-hoists and inclines. Then the remainder is usually moved by some form of steam conveyor. On one section, however, all three cuts were removed by means of car-hoists and cable inclines.

CHANNELING.

The Channeler, Fig. 51, is an entirely new machine to canal excavation and one destined apparently to become an important feature. While it increases the cost to some extent, this is more than balanced by the greater cross-section, the added security to vessels from the vertical walls, and the assistance it gives to future building of docks.

The operation of channeling consists of cutting a vertical groove at each edge of the canal excavation from top to bottom of each successive lift. Then the rock between the channeled grooves, when blasted, falls away, leaving on either side a smooth vertical wall.


SANITARY DISTRICT OF CHICAGO.
MAP & PROFILES
MAIN DRAINAGE CHANNEL
CHICAGO TO JOLIET

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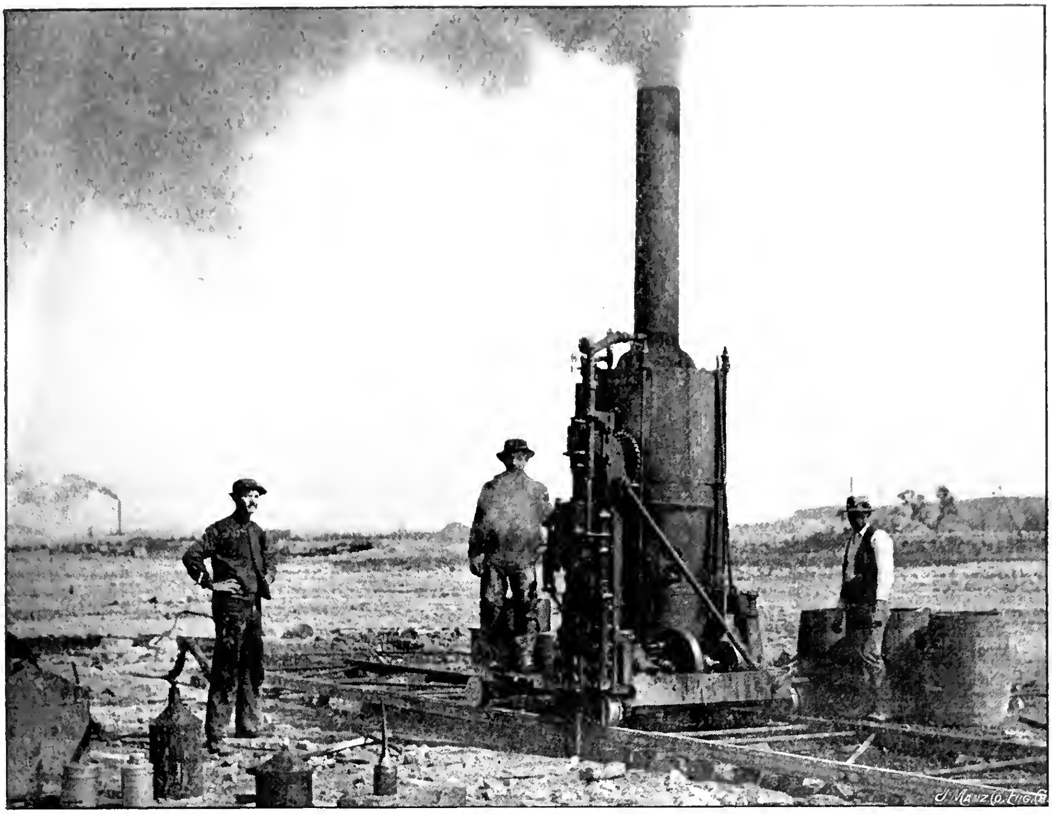


FIG. 51. CHANNELING MACHINE, USED ON ALL ROCK SECTIONS.

The channeler itself consists of a vertical boiler placed on a heavy rigid frame resting on trucks and running on a 30-foot section of track. To this frame is attached on one side a vertical cylinder of about 10-inch stroke, to the piston of which, working downward, is fastened the channel bar, as an extension. Thus the stroke of the channel bar is the direct stroke of the piston. The depth of cutting with any one bar is regulated by a feedscrew, allowing the cylinder a vertical motion of about two feet. On reaching this limit the bar is removed, the cylinder raised and, with a new bar, two feet longer, cutting is again begun. In order to prevent possible jar or breakage, in case a vein or pocket in the rock is encountered, a steam cushion is arranged for the piston.

Two engines are in use on the channeler. One runs the movement of the piston and bar, while the other regulates the motion on the track. The total weight is about 11,000 pounds.

The channel bar generally used is 6 inches wide and one inch thick. The bars are made in lengths of 2, 4, 6, 8, 10, 12 and 14 feet. About a foot from the lower end of the bar two projections begin to develop, one on each side, but facing opposite directions. At the cutting edge these form the gauge. This gauge varies inversely as the length of the bar, being $2\frac{3}{8}$ inches in the shortest or 2-foot bar, and decreasing one-eighth inch for each consecutive bar.

In operation the channeler moves back and forward over its

30-foot track with the bar continually working at about 250 blows per minute. The speed and length of stroke are regulated by the operator. On account of its build, a channeler needs a space of about 6 inches between the line of the cut and the wall; therefore, for each lift after the first that is removed, an offset of 6 inches becomes necessary. Thus with three lifts we have a total width at the surface of 162 feet. See accompanying sketch (Fig. 50.) The rate of channeling varies with the quality of rock and with the lift. First lift channeling was done at the rate of from 130 to 200 square feet per day of 10 hours, while second and third lift channeling varies between 60 and 100 square feet per day. The second lift work is harder than the first for three principal reasons: the proximity of the wall of the first lift, the increasing hardness of the rock and the partially shattered condition of the rock due to blasting the previous lift. In the third lift is the additional disadvantage that care must be taken not to go below grade.

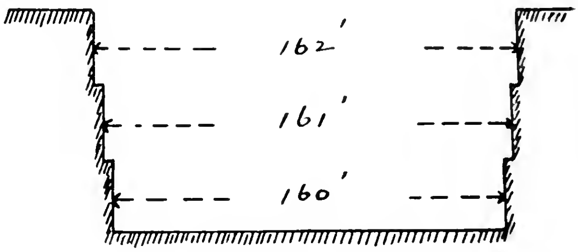


Fig. 50.

Below is given a table of cost and rate of channeling on Sections 7, 8, 9 and 10 during a period of 13 successive months—January 1st, 1894, to February 1st, 1895. Each square foot of channeled surface corresponds to three cubic yards of excavation:

Section.	Sq. Ft. Channeled.	Days (10 hours).	Cost Per Sq. Ft., Cts.	Sq. Ft. Per Day.
No. 7	98,043	1,170.2	11.73	83.80
*No. 8	42,000	300.0	7.50	140.00
No. 8	201,558	2,339.3	11.10	86.16
No. 9	182,167	1,992.5	12.16	91.40
No. 10	202,192	2,638.3	11.81	76.64

Time given is the actual working time, all delays of an hour or more having been deducted.

Cost of repairs made in the field is included, but the cost of broken parts or repair of machine in shop was not available and is not included.

The scale of ages for channeling on various sections as used in the computations of cost above given is as follows:

	Sec. 7.	Sec. 8.	Sec. 9.	Sec. 10.
Channelerman	$3.00	$3.25	$3.25	$2.75
Fireman	1.75	1.75	1.75	1.75
Laborer	1.50	1.50	1.50	1.50
Team (occasional)	3.50	3.50	3.50	3.50
Foreman (for entire section).	2.75	2,75	2.75	....
Coal oil and waste	1.75	2.25	2.25	1.75

For further information about channeling with illustrations see Engineering News, August 29th, 1895, and Railway Review, August 25th, 1894.

*This item was nearly all first lift channeling done between January 1st and May 1st, 1894.

DRILLING.

Practically all drilling is done mechanically with power furnished either by steam or by compressed air.

Compressed air is used on nine out of fifteen rock sections. The method usually adopted is to have a large air compressor near the center of each section with air mains of 8 to 10 inch pipe running from the compressor to the berm of the channel, there dividing into two 6 or 8 inch pipes, one leading along the berm in either direction. From these pipes, feeders head off whenever necessary to supply the drills, there being one 2-inch feed pipe from 175 to 230 feet in length, and from one to three drills for each working face. The air pressure maintained at the compressor is about 80 to 90 pounds, and there is comparatively small leakage in the pipes.

In drilling by steam the power is furnished by boilers located near the drills in the pit, one boiler sometimes furnishing steam for several drills.

The drills in use are all made either by the Ingersoll Sergeant Drill Co. or the Rand Drill Co.

The principle of the machine as in the channeler is that of a simple piston. The steam or air comes from the feed pipe through a line of hose to a vertical cylinder with downward acting piston to which is fastened the drill bar as a direct extension. Thus it is a "plunge" drill striking a sharp quick blow with the full strength of the air or steam in the cylinder. In returning after each stroke a ratchet and pawl device turns the drill bar partly around.

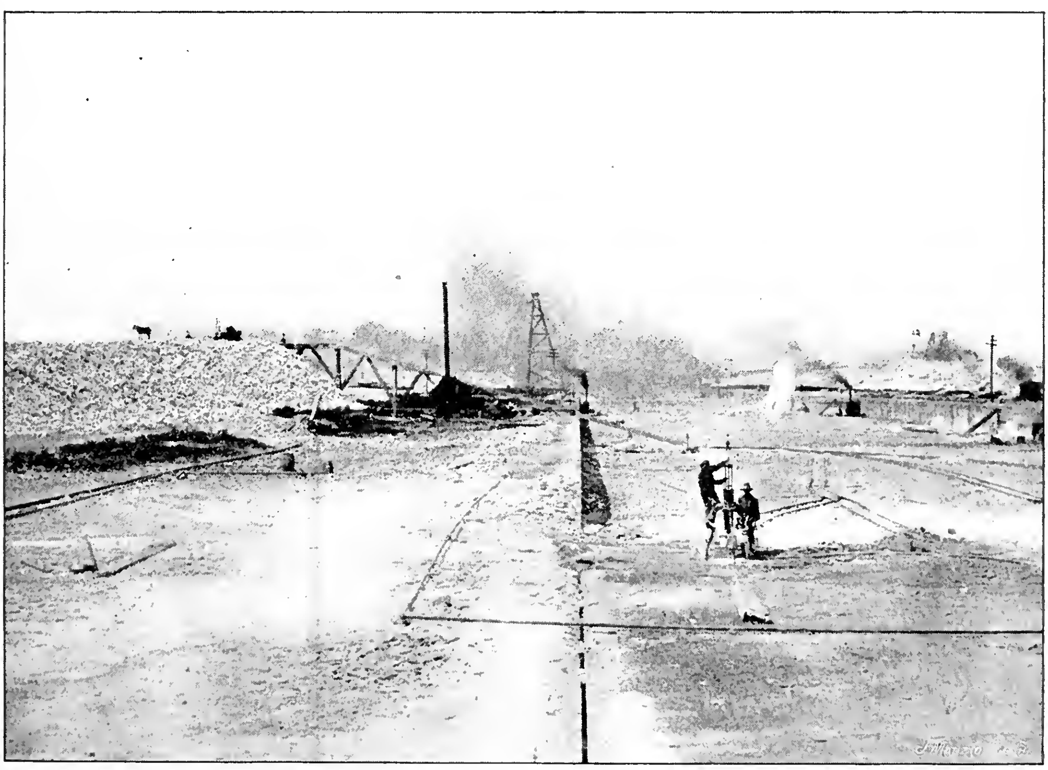


FIG. 52. CHANNELED SLOT AND POWER DRILL.

The total weight of a drill is about 900 lbs. Its maximum stroke is $6\frac{1}{2}$ inches, and the cylinder is $3\frac{1}{2}$ inches in diameter.

Drill bars come in lengths of 2, 4, 6, 8, 10, 12 and 14 feet. The diameter of the starter or two-foot drill is three inches and each successive length decreases by one-fourth inch. The cutting edge of a drill bar is usually a + or an ×, the latter usually giving the better results.

The daily expense of a drill is approximately as follows:

STEAM DRILL.		COMPRESSED AIR DRILL.	
Drillman	$2.00	Drillman	$2.00
Helper	1.50	Helper	1.50
1-3 Fireman	.50	Cost of air	1.50
Coal, oil, waste	1.25	Oil and waste	.10

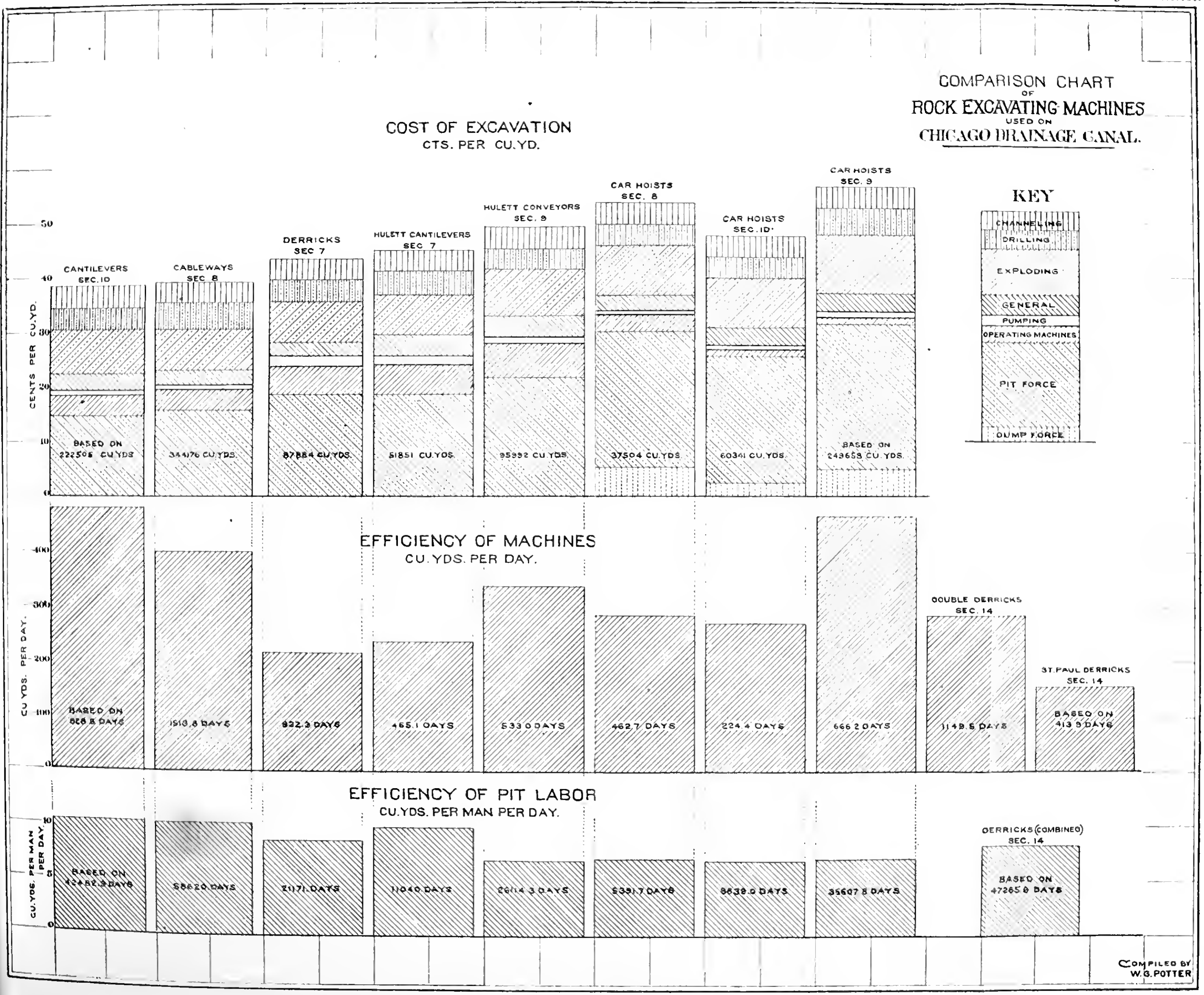
Repairs and blacksmithing are not included in above table.

In operation holes are drilled from five to seven feet apart and from six to nine feet from the working face. On some sections two rows of holes are drilled across the channel, thus making one blast of about fifty holes.

FIG. 53. BLAST MADE WITH 1,050 LBS DYNAMITE.

EXPLODING AND BLASTING.

Blasting (Fig. 53) on the channel is being done almost entirely with 40 per cent dynamite. Experiments show that this percentage of nitro-glycerine is the most economical. Higher grades have a


COMPARISON CHART
OF
ROCK EXCAVATING MACHINES
USED ON
CHICAGO DRAINAGE CANAL.
COST OF EXCAVATION
CTS. PER CU. YD.
CENTS PER CU. YD.
CANTILEVERS
SEC. 10
CABLEWAYS
SEC. 8
DERRICKS
SEC. 7
HULETT CANTILEVERS
SEC. 7
HULETT CONVEYORS
SEC. 9
CAR HOISTS
SEC. 8
CAR HOISTS
SEC. 10
CAR HOISTS
SEC. 9
BASED ON
222506 CU. YDS.
344176 CU. YDS.
87884 CU. YDS.
51851 CU. YDS.
95992 CU. YDS.
37504 CU. YDS.
60341 CU. YDS.
BASED ON
249658 CU. YDS.
KEY
CHANNELING
DRILLING
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PUMPING
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PIT FORCE
DUMP FORCE
EFFICIENCY OF MACHINES
CU. YDS. PER DAY.
CU. YDS. PER DAY.
DOUBLE DERRICKS
SEC. 14
ST. PAUL DERRICKS
SEC. 14
BASED ON
868.8 DAYS
1513.8 DAYS
832.3 DAYS
465.1 DAYS
533.0 DAYS
462.7 DAYS
224.4 DAYS
666.2 DAYS
1149.5 DAYS
BASED ON
413.9 DAYS
EFFICIENCY OF PIT LABOR
CU. YDS. PER MAN PER DAY.
CU. YDS. PER MAN PER DAY.
DERRICKS (COMBINED)
SEC. 14
BASED ON
42482.3 DAYS
58620 DAYS
21171 DAYS
11040 DAYS
26114.3 DAYS
53917 DAYS
8639.0 DAYS
35607.8 DAYS
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tendency to break the rock in pieces too large to handle without being again blasted.

Exploding is done both by fulminating caps and fuses, and by caps, wires and electricity. The latter is considered the better method because of the explosive forces being exerted more nearly simultaneously, and because of the increased safety to men.

The dynamite comes in cartridges about 6 inches long and $1\frac{1}{2}$ inches thick, weighing three-quarter pounds each. From ten to twenty-five of these cartridges are loaded and tamped in each hole, the percussion cap being about in the middle. In firing with electricity two wires run from each cap or exploder to the surface and there connect in series with wires from all the other holes. The two end wires lead off to a battery at a safe distance. By this means the whole working face 160 feet wide is blasted at one shot. From 0.6 to 1.2 pounds of dynamite are used per cubic yard of excavation.

For cost of exploding per cubic yard, see Tabulation of Cost of Excavation (Fig. 54). In obtaining the figures there given, dynamite fuses, caps, etc., are estimated to cost 12 cents per pound of dynamite. Powdermen receive $1.50 and $2 per day.

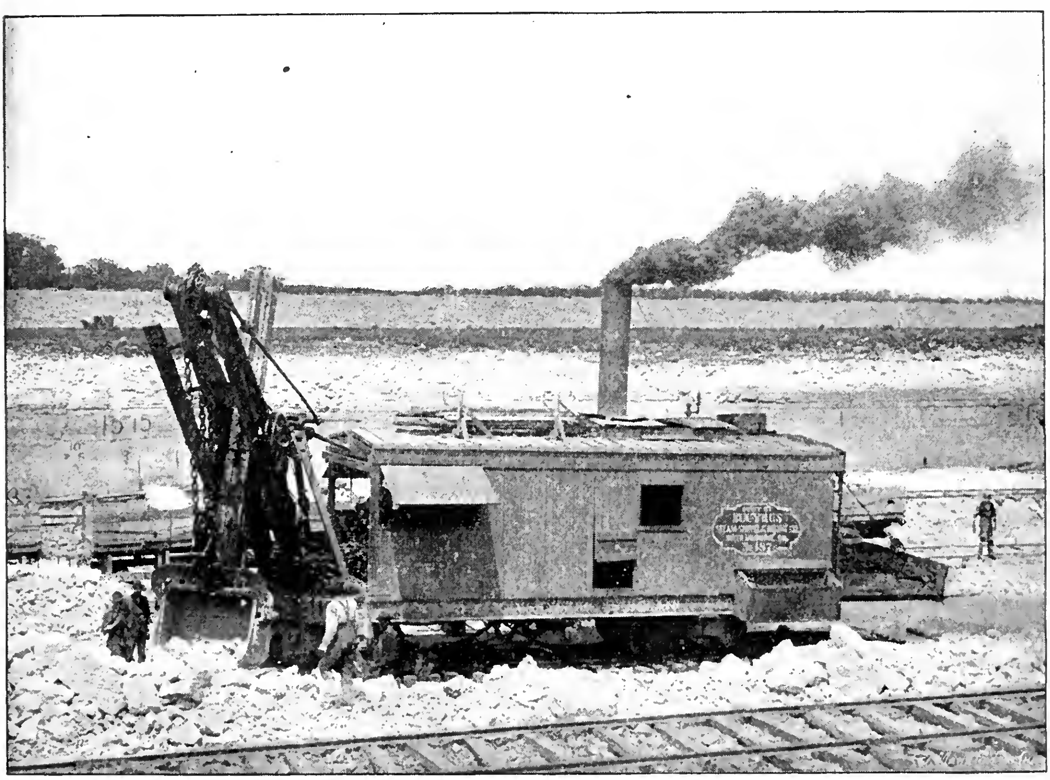


FIG. 55. STEAM SHOVEL LOADING ROCK ON SECTION 15.

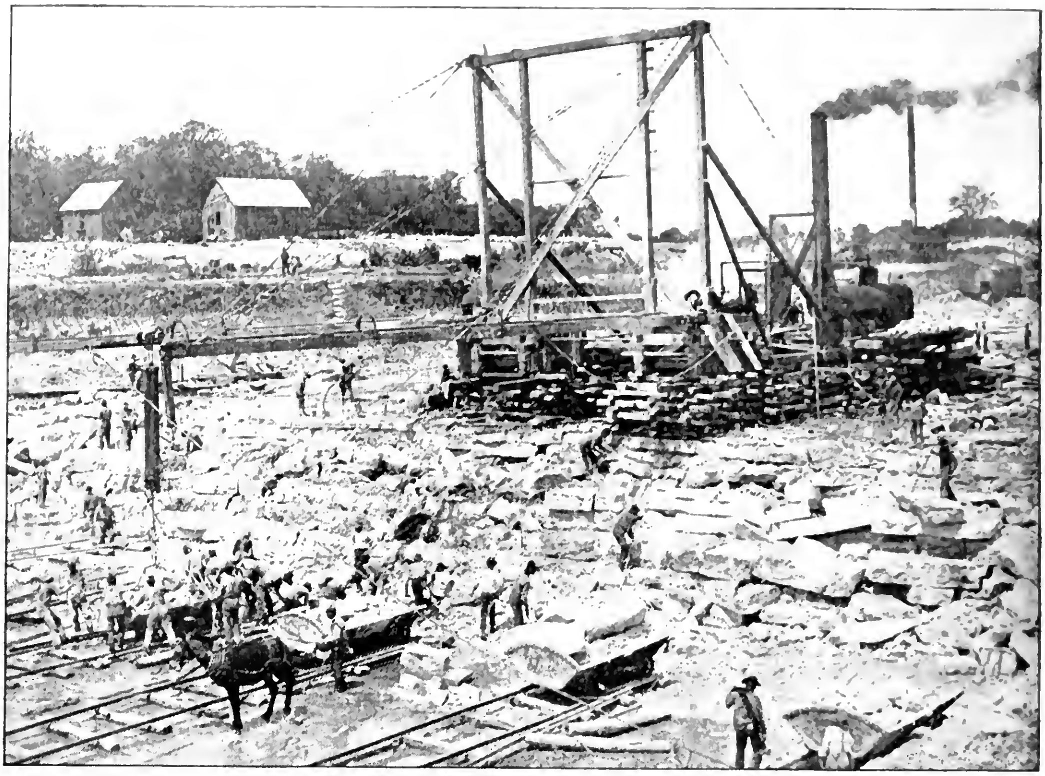


FIG. 56. AIR LIFT LOADING DEVICE AND TRAM CAR.

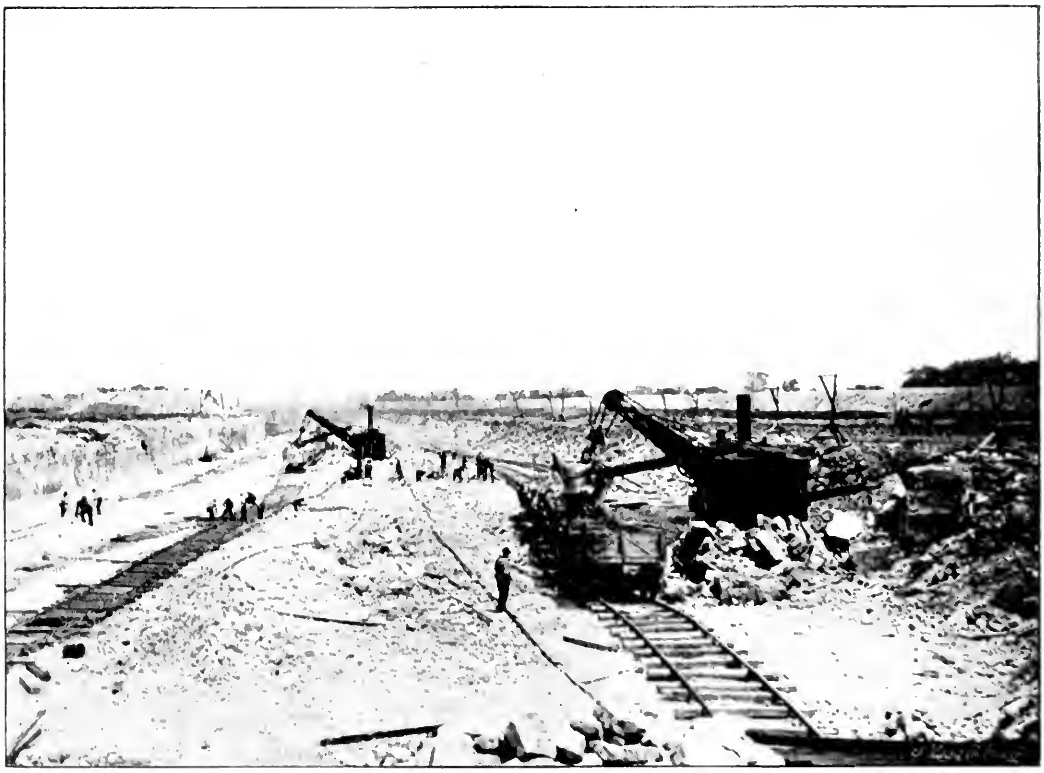


FIG. 57. STEAM SHOVEL LOADING ROCK ON SECTION 15. LOCOMOTIVES HAULING CARS ON STANDARD GAUGE TRACK AS MEANS OF CONVEYING.

CAR HOISTS.

For excavating and wasting the first cut, the method generally used, aside from carts and wagons, was that of the car hoist. This, in brief, consisted of hauling loaded cars by means of a hoisting engine and cable from the pit to the spoil bank.

There were in use three general methods of operating the car hoists which will be separately discussed.

METHOD I.—FIXED INCLINE AND SPUR TRACKS.

In this method (Figs. 58, 59), used on Sections 8, 11, 12, 13 and 15, a number of spurs, usually not more than 150 feet in length, were laid both in the pit and on the spoil bank, all connecting by switches with a main track leading up over a fixed timber incline. This incline was at a right angle to the channel, and had a slope of about 30 degrees, with a horizontal length of about 40 feet in the pit and 85 feet in the berm. At the head of this incline was placed a hoisting engine with a hoisting cable extending to the bottom. On each of the pit tracks, single cars of about one cubic yard place measurement capacity were loaded by hand by the pit force. When full each car was hauled by a mule to the foot of the incline. Here the car was attached to the hoisting cable and drawn to the top of the spoil bank. From there the car was again hauled by a mule over one of the spurs to its dumping place.

The pit force consisted of about 40 to 45 men, 1 water boy, 1 mule and driver and 1 foreman. The dump force consisted of 1 engineer of hoist, 1 hoist runner, 1 mule and driver and a few dump men. Eight cars were generally in use.

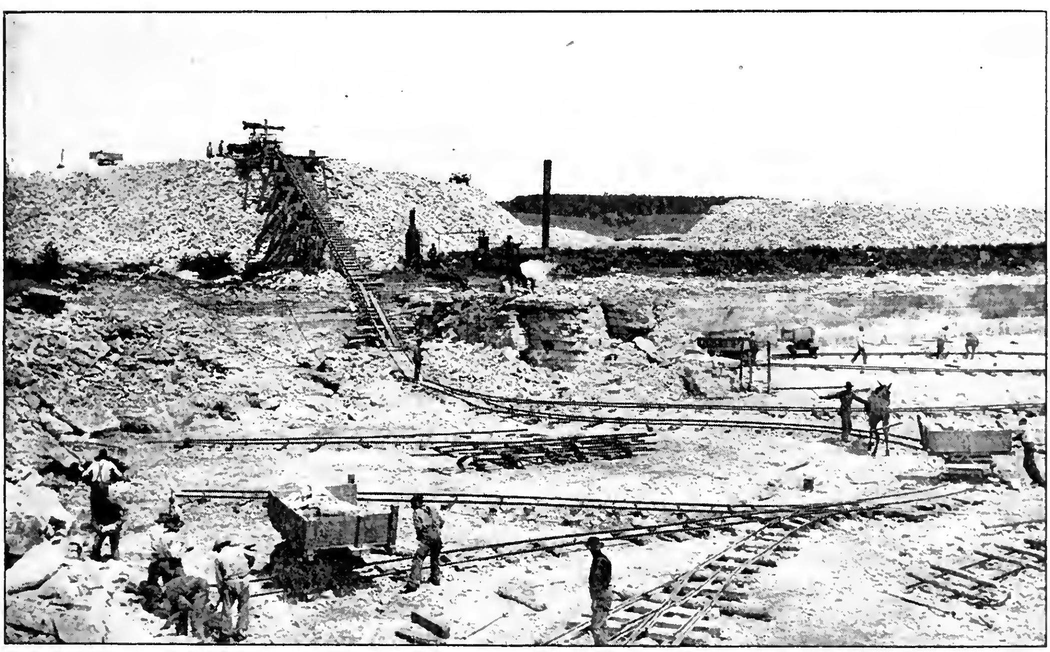


FIG. 58. LOADING BY MANUAL LABOR AND TRAM CAR CONVEYING.

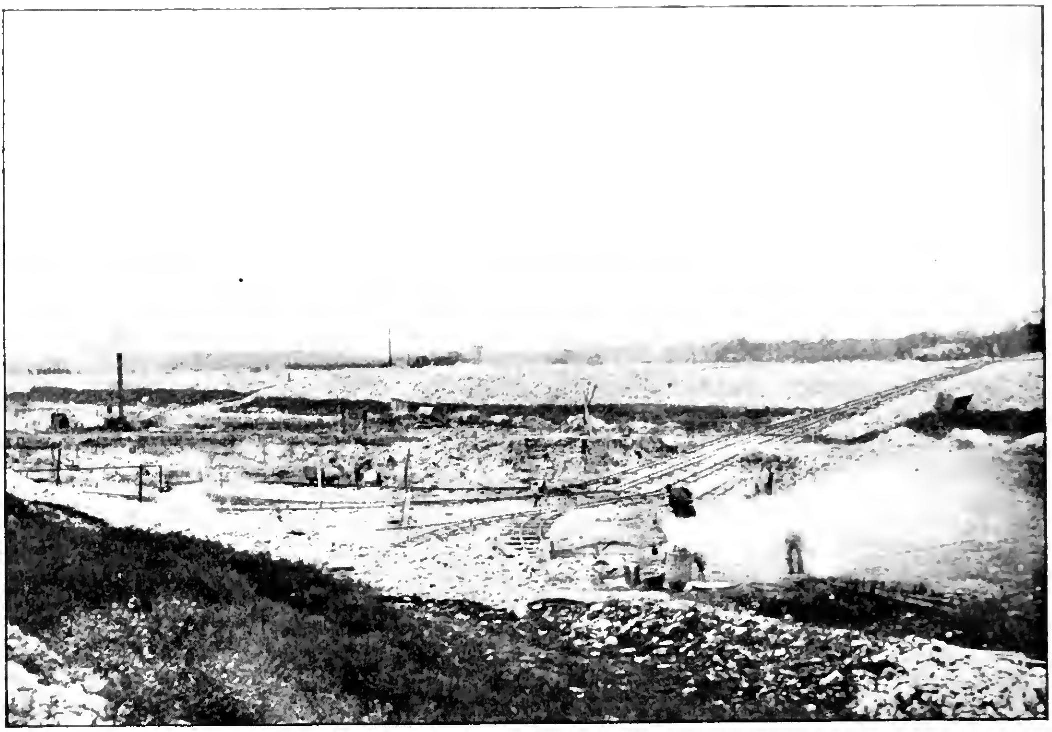


FIG. 59. LOADING BY MANUAL LABOR AND TRAM CAR CONVEYING.

After the working face was excavated to the limiting economical distance from the incline, the trestle was torn down and rebuilt at the new face. The two highest bents of trestle being mostly buried under the spoil were abandoned and left in position.

METHOD II.—NATURAL INCLINE AND LOOP TRACK.

This method, as used on Section 10, was noticeable by the absence of nearly all timber work. After drilling and blasting the full width of the channel, the material was left in place in a wedge-shaped strip extending from the floor of the cut at a point 40 feet from the channel line to the natural surface at that line. Upon the spoil bank, which also sloped upwards one foot in ten, was laid a single track about 150 feet long. At about 75 feet from the channel this track diverged into two tracks which led down over the berm and above mentioned strip of blasted rock to the bottom where they came together in a loop at the far side of the channel. The total length of track on this loop was about 375 feet, the curve being of 15 feet inside radius, the track gauge being 3 feet. This made the shortest haulage of any hoist system, and as the track was simply placed on stringers on the rock and easily moved, it was the least costly in regard to maintenance and capital invested.

In operation, trains of four cars, each of one and one-half yard in place measurement capacity, were loaded by hand in the pit, the cable immediately attached and the train hauled to the spoil bank. Here each car was side-dumped. The train was then re-

turned to the pit by the other track and landed in behind the next loading train. Three trains were in use on each hoist, two being loaded while the third was being dumped. The pit force consisted of 1 foreman, 1 water boy and about 35 laborers. The dump force consisted only of the hoist engine man and four laborers dumping cars.

However after the hoist work was finished a cart force was necessary to follow and remove the strip on which the track had been laid.

Further information may be found with illustrations in Engineering News, September 12th, 1895, Railway Review, September 8th, 1894.

METHOD III.—DOUBLE HOIST AND DIAGONAL INCLINE.

The third method (Fig. 60), used on Section 9, was very different from either of the preceding. Two working faces were generally used, each being horizontally inclined at an angle of about 30 degrees with the channel, thus giving very long permissible loading lines. These two faces were in some hoists parallel to each other and in others they were inclined in opposite directions.

Leading from each of these faces was the loading track. These tracks together left the pit over a diagonal double track trestle, from the top of which they again diverged leaving space between them on the spoil bank for the hoisting engine. Sidings for the passing of

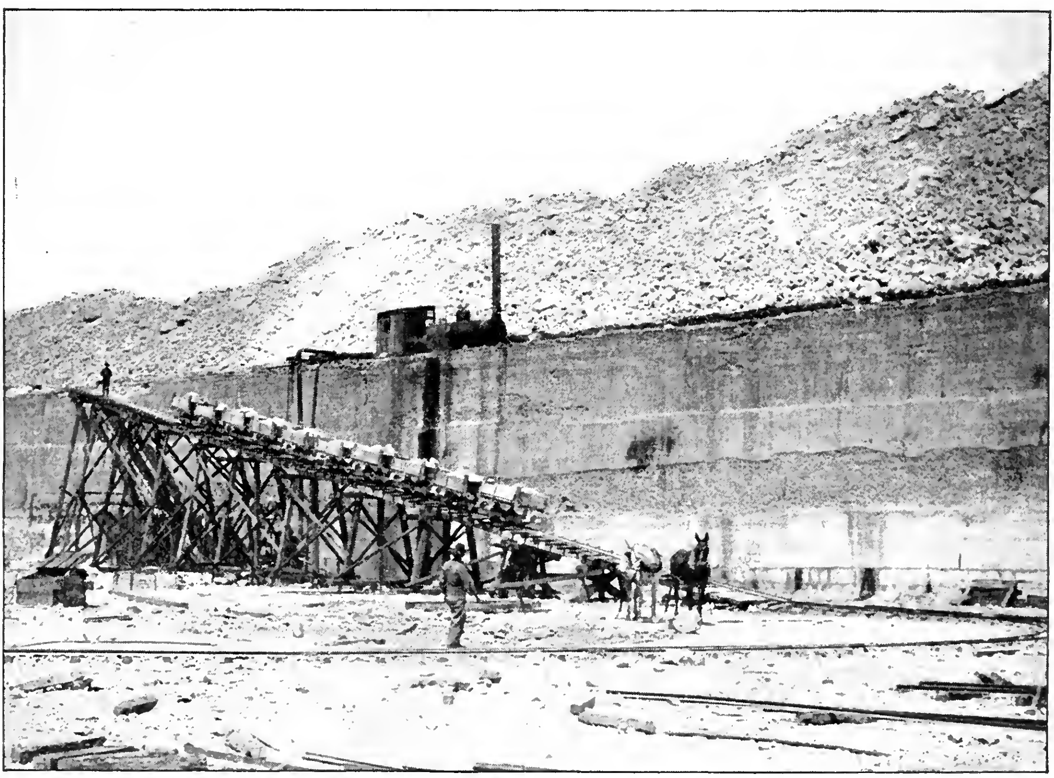


FIG. 60. TRAM CAR CONVEYING ON SECTION 9.

empty and loaded trains were maintained with each track both in the pit and on the spoil bank. The length of each main track was approximately 150 feet on trestle, 300 to 800 feet in pit, and 600 to 1,000 feet on spoil bank.

In operation, trains of twelve cars of one-half cubic yard capacity were drawn to the foot of the trestle by mules, raised to the top of the spoil bank by cable and then drawn to the dumping ground by mules. Two cables, one for each track, were operated by the one engine by means of a double drum.

The pit force for one double hoist consisted of 2 foremen, 2 water boys, 3 teams and about 75 men. The dump force consisted of 1 engine man, 1 fireman, 3 teams and 10 men.

By this double face method a very high efficiency is obtained at a cost not greatly increased, as is seen by the Comparison Chart shown later.

Not only is it good for first lift work like the other hoist methods, but also for second and even third lift, the only change being to use ten instead of twelve car trains. Figures given later are for all three lifts for this method.

Further information with illustrations may be found in Engineering News, September 5th, 1895, and Railway Review, September 1st, 1894.

HULETT CONVEYOR.

The Hulett McMyler Conveyor, or derrick and incline, is one of the experimental methods of rock excavation, and while at first it did not prove as successful as expected, it has been modified and improved into a fairly good method.

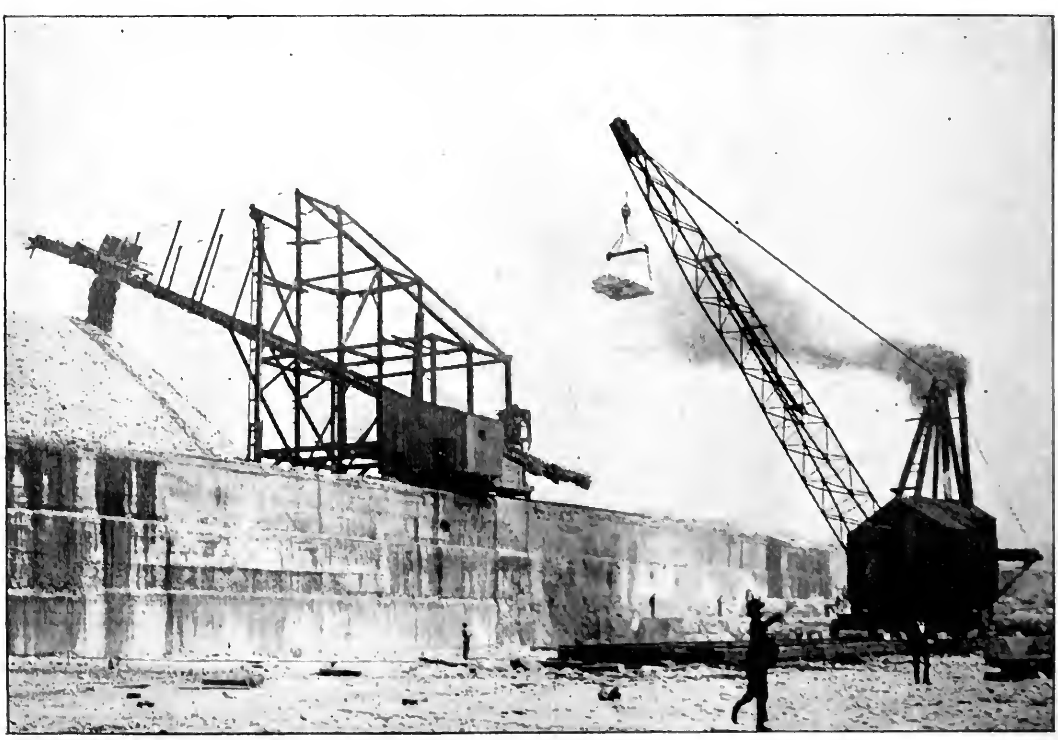


Fig. 61. High-Power Derricks Used on Sections 7 and 9

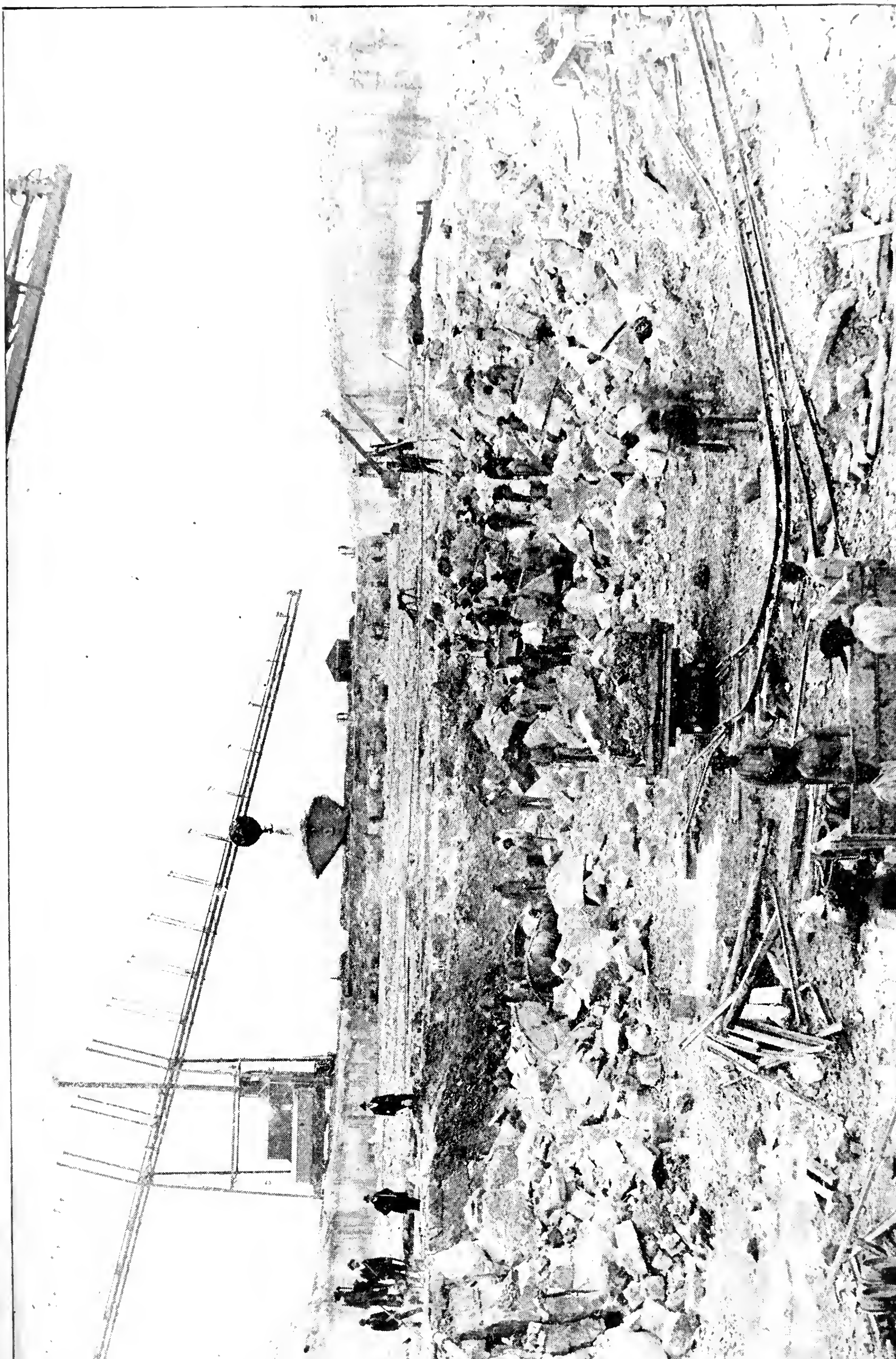


FIG. 62. ROCK IN DRAINAGE CHANNEL AND WATERWAY AFTER BLASTING. TRAM CAR CONVEYING BROWN CANTILEVER IN BACKGROUND.

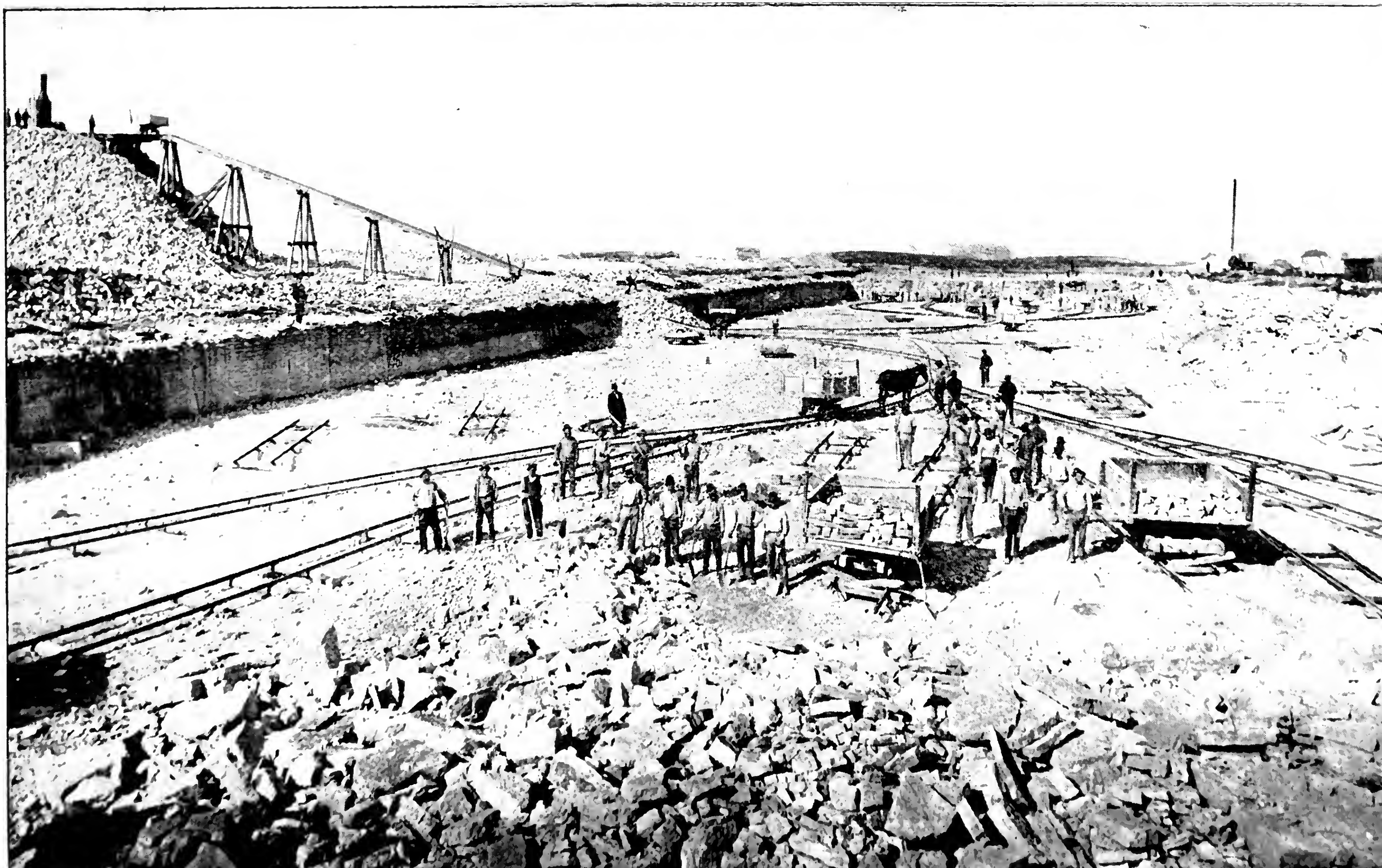


Fig. 63. Removing Excavated Material from Drainage Channel and Waterway. Tram Car Conveying.

Originally four machines (Fig. 61) were in use, two each on Sections 7 and 9, but the two on Section 7 were rebuilt in 1894. They will be described later as the Hulett Derrick and the Hulett Cantilever.

The Hulett Conveyor, as used on Section 9, consists of two separate machines and herein lies the great objection. Any conveyor which necessitates two handlings of each bucket must be more expensive to operate, and consequently either be of greater efficiency or else fail of economy. Two sets of engines and boilers, two different operating crews, and two sources of possible delays and breakdowns all tend to greater cost and lower efficiency.

The plant described in brief is as follows: In the center of the pit on a track of 20 foot gauge, is a self-contained steel revolving derrick of 50 H. P. with a boom of 70 feet radius. Just outside of the excavation line on the natural ground is another machine in the shape of a timber incline which moves on two tracks 45 feet center to center. Both this incline and the derrick move along these tracks parallel to the canal at will. This incline, the lower end of which is about even with the natural surface and projecting over the pit, rises at an angle of approximately 25 degrees for a distance of 170 feet. Its upper end is about 70 feet from the ground. A car of about 4.5 cubic yards capacity, in place measurement, runs on a track on the incline, being drawn by a cable from a 75 H. P. engine, assisted by heavy counter weights. In operation, buckets or "skips" are loaded in the pit by hand. Then the derrick lifts the bucket, swings it up and around till above the incline car, and dumps it into the car. The car is then drawn up and automatically dumped by striking a fixed trip near the top. The working face is directly across the channel, and eight buckets are constantly in use with five laborers to a bucket. Illustrations and further information for this machine may be found in Engineering News for September 5, 1895, and Railway Review, September 1, 1894.

The cost of derrick is said to be about $15,000, and of incline $10,000.

For comparison with other methods see Summary.

HULETT DERRICK.

On Section 7, the system as followed on Section 9 was abandoned, and the machines were rebuilt (Fig. 68) on altogether new plans.

The derricks and inclines were made independent of each other, and each was built to convey directly from pit to spoil bank. Of these two the derrick will first be described. Originally used in the pits, the new derricks were placed one on each berm on tracks running parallel to the channel. The boom was lengthened to 123 feet, turn table strengthened, and heavy counterweights added. With a new radius of 97 feet each derrick easily reaches the center line of excavation.

In operation the skips are loaded by hand and then raised by the derrick. By means of a special device the buckets are dumped

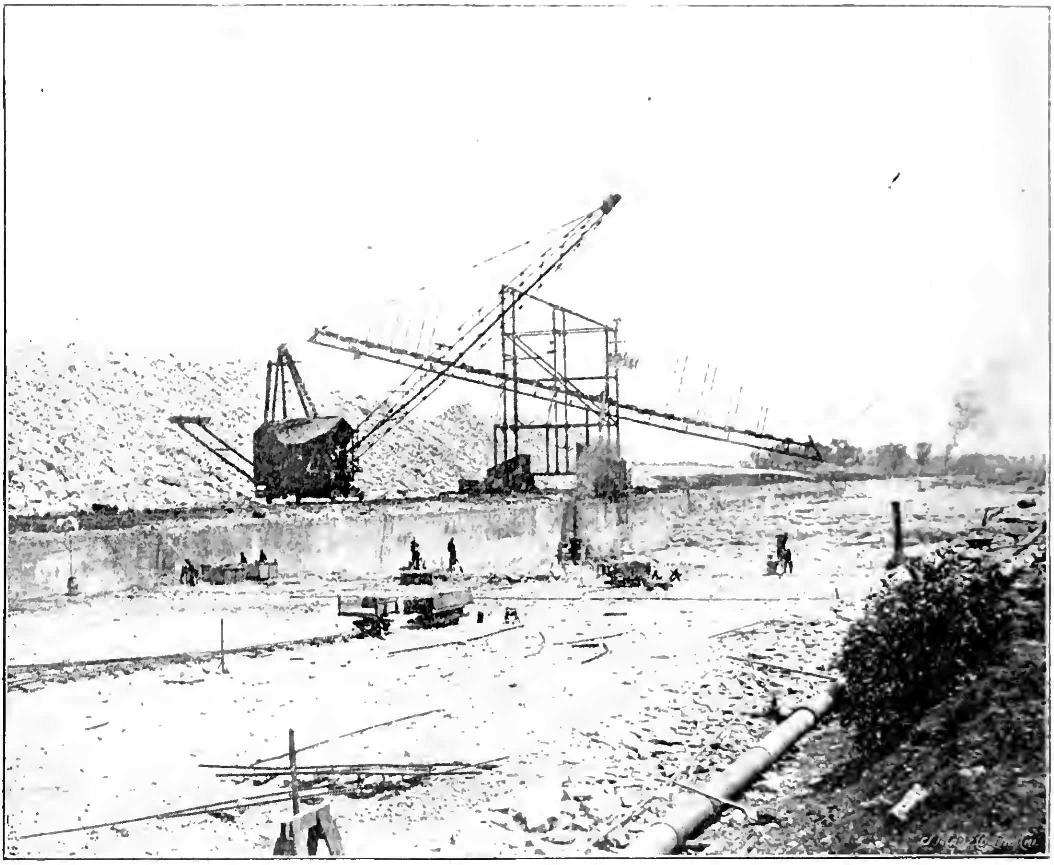


FIG. 68. GENERAL ARRANGEMENT OF MCMYLER DERRICK AND HULETT CANTILEVER USED ON SECTION 7.

in mid-air while revolving over the spoil bank, and the complete revolution made at high speed without stopping. Four laborers are used for each bucket, and eight buckets to a face. The cost of a derrick is about $15,000.

Further information with illustrations may be found in Engineering News, August 22d, 1895, Railway Review, August 18th, 1894.

HULETT CANTILEVER.

After the abandonment of the Hulett conveyors on Section 7, the former "inclines" were rebuilt and converted into wooden or timber cantilevers (Figs. 68, 69, 70). This cantilever, as now in use, consists of a frame work or tower, resting on trucks and tracks running parallel to the channel, surmounted by two cantilever arms inclined at an angle of 15 degrees with the horizontal. One arm extends downward almost to the center of the channel, and the other upward over the spoil bank. On a track on this cantilever runs a trolley supporting the carriage through which runs the hoisting cable. In operation, the loaded bucket is raised by the hoisting rope until it reaches the carriage in which it is securely locked by ingenious mechanism. The trolley, carriage and bucket then travel up the track until near the upper end of the cantilever, the bucket strikes a fixed block and by it is automatically unlocked and dumped.

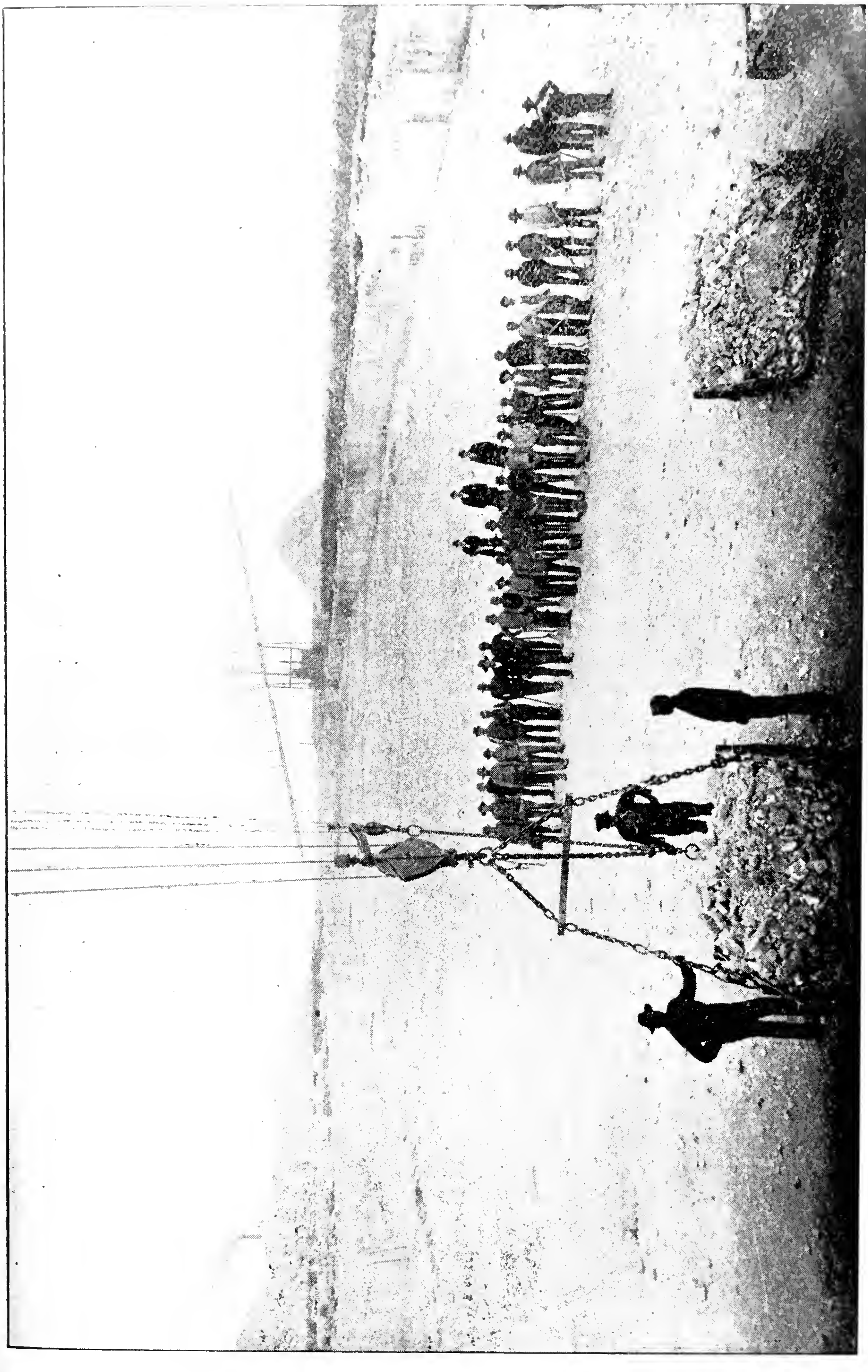


Fig. 64. Method of Removing Rock from Drainage Channel and Waterway. Cable Hoist Skips.

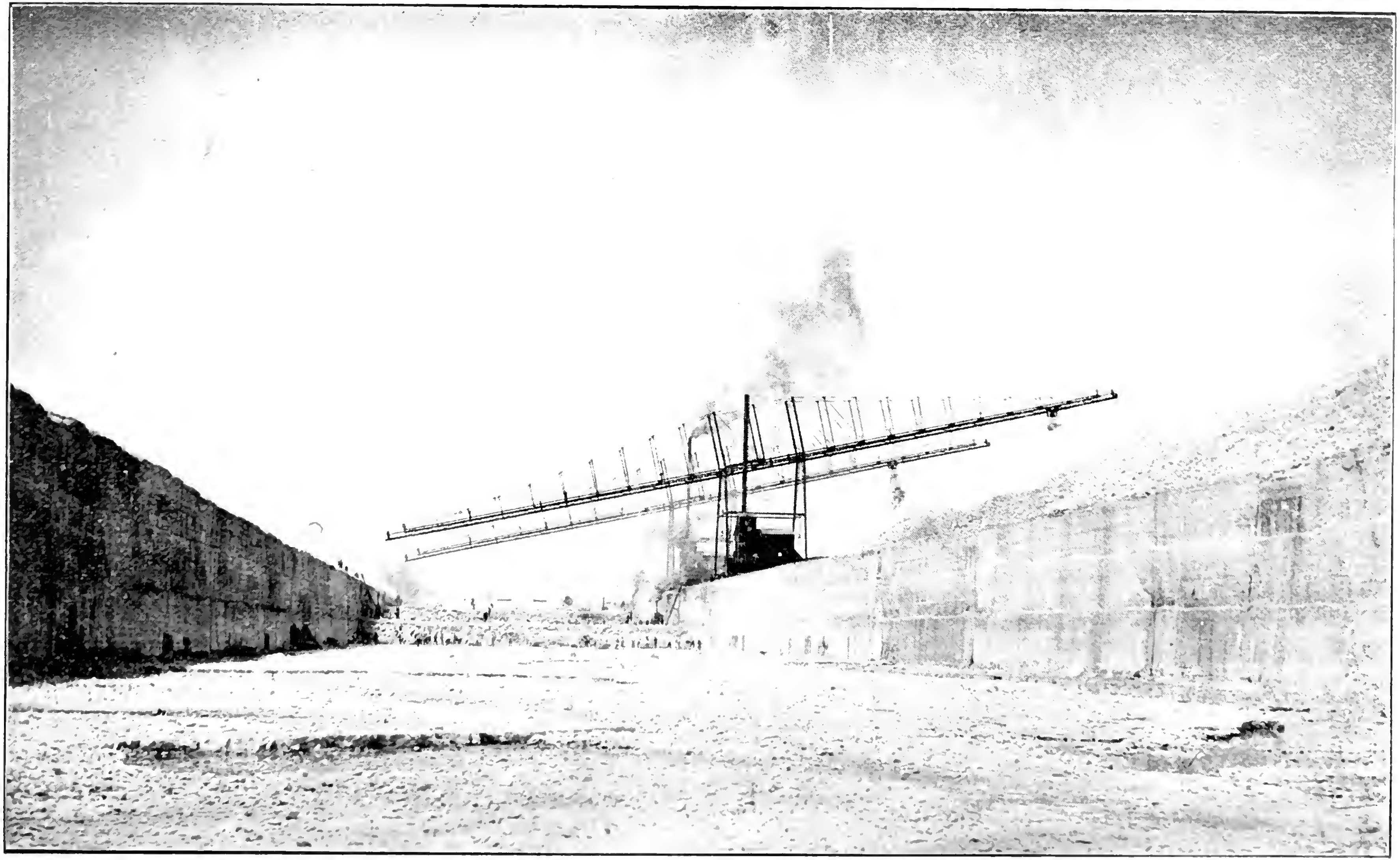


FIG. 65. THE BROWN CANTILEVER CONVEYOR; ALSO COMPLETED PRISM OF CHANNEL, ROCK CUT BEING 35 FEET.

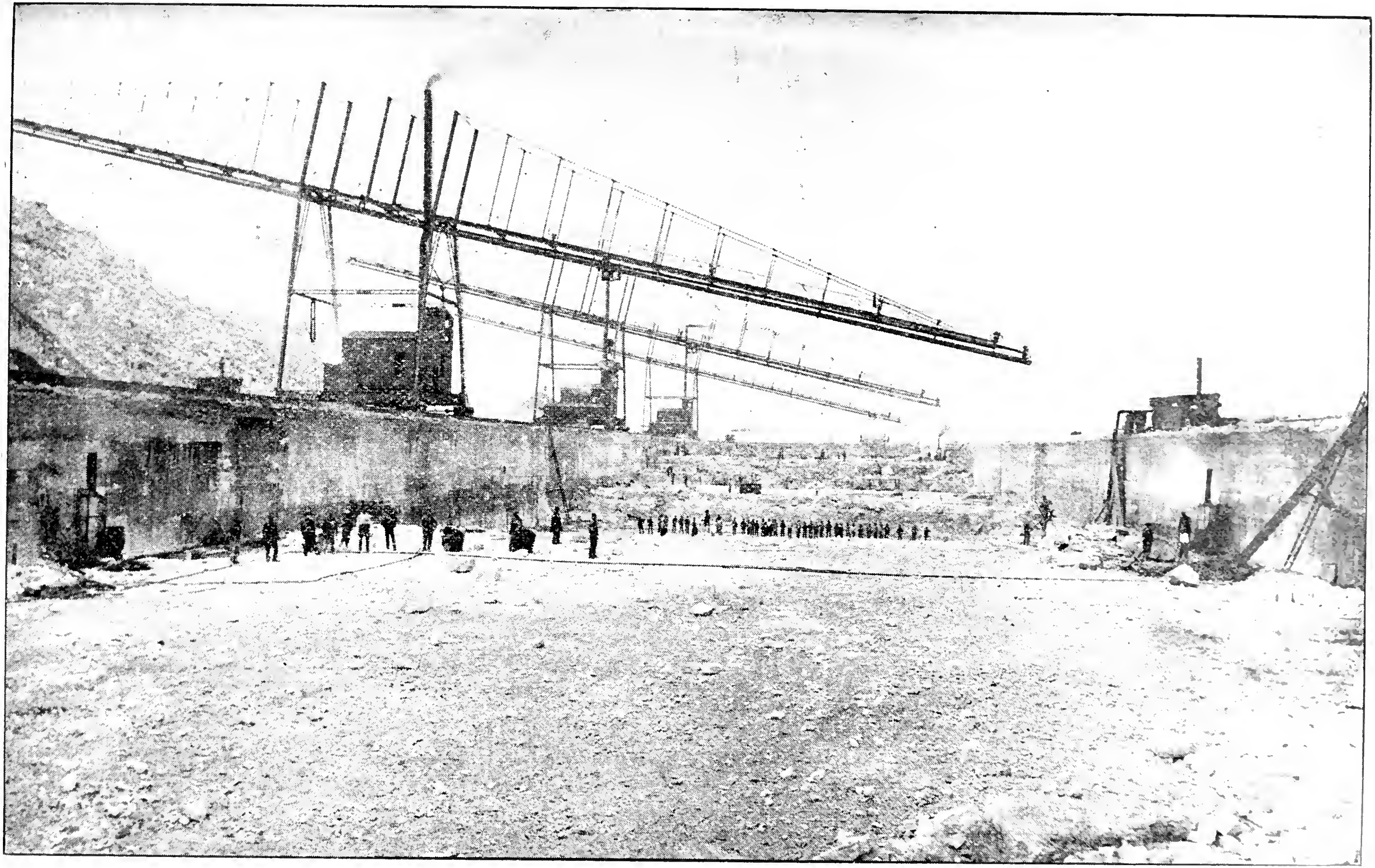


Fig. 66. Excavation in Rock for Drainage Channel and Waterway. Full Depth in Center. Brown Cantilever Conveyor.

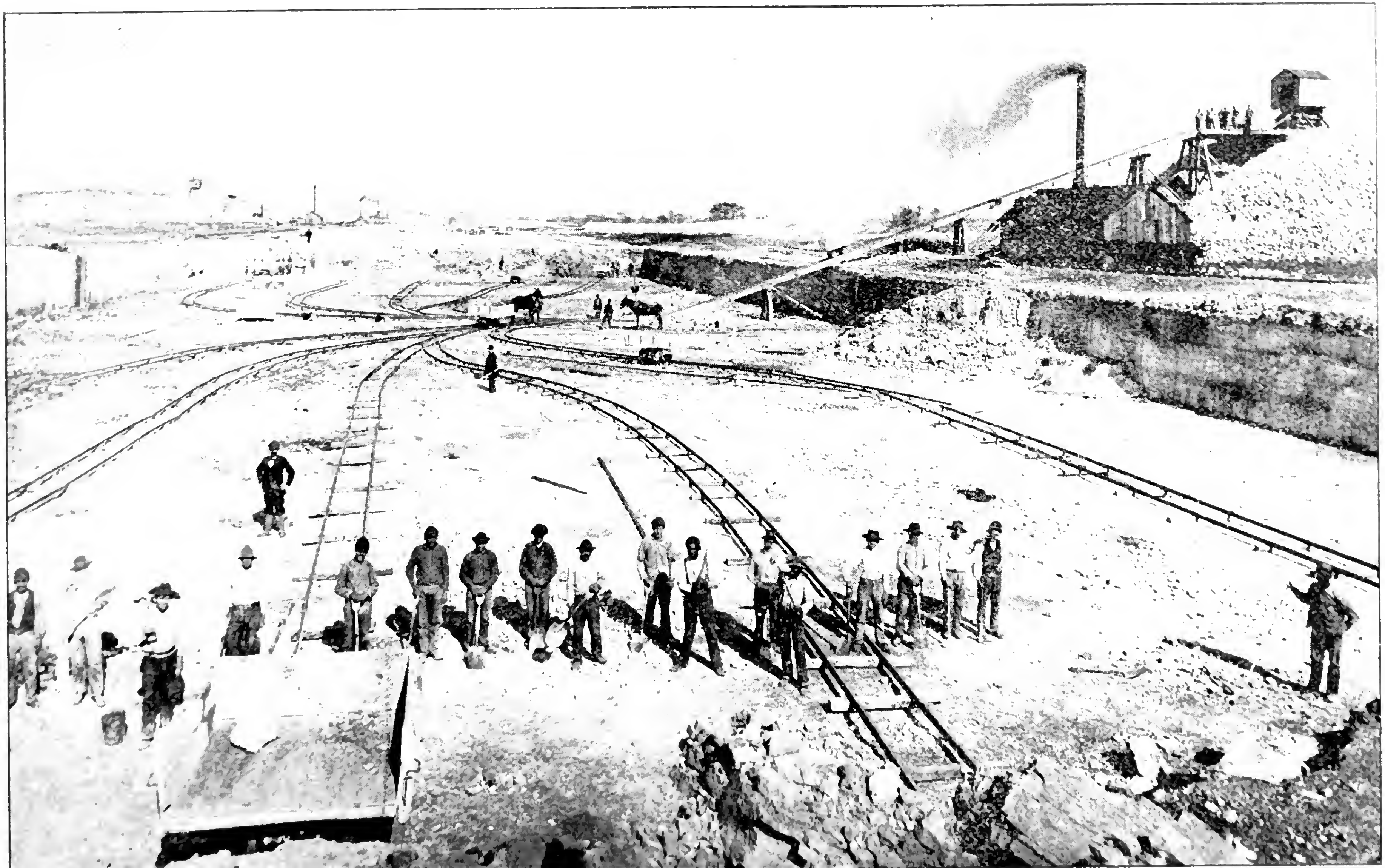


FIG. 67. DRAINAGE CHANNEL AND WATERWAY IN ROCK. FULL WIDTH AND ONE-THIRD REQUIRED DEPTH. TRAM CAR CONVEYING.

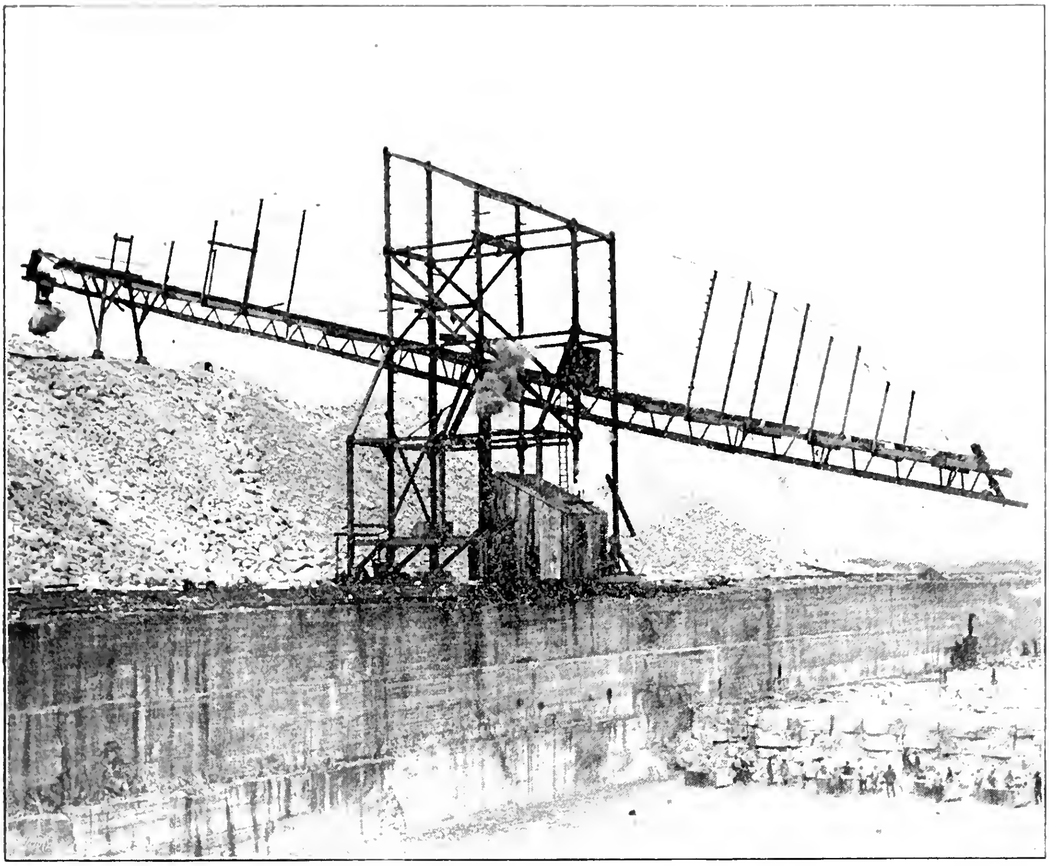


FIG. 69. THE HULETT DERRICK USED IN SECTION 7—SHOWING SKIPS AT FACE.

One of these cantilevers is on each side of the channel, each working to the center line.

The cost of these machines is from $10,000 to $12,000 each. For comparison with other conveyors see Summary.

Further information with illustrations may be found in Engineering News, August 22d, 1895.

DOUBLE DERRICKS.

The Hulett Derricks on Section 7 are said to have the longest single boom of any traveling derricks ever used. The ones to be described (Fig. 70) now are the double boom traveling derrick designed by ex-City Engineer Dion Geraldine of Chicago, and used on Section 14.

Four of these derricks are in use working in pairs on opposite berms. Each is mounted on a 28-foot turn table, and on a framework which in turn is mounted on rollers for movement parallel to the channel. In this framework are located the engines, boilers, etc. Rising vertically from the turn table is a tower 110 feet high, and projecting in opposite directions are the two steel trussed booms, each about 160 feet long. Lines for moving these booms vertically run from the engine over sheaves at the top of the vertical tower and then to fall blocks on the booms. Running over each boom

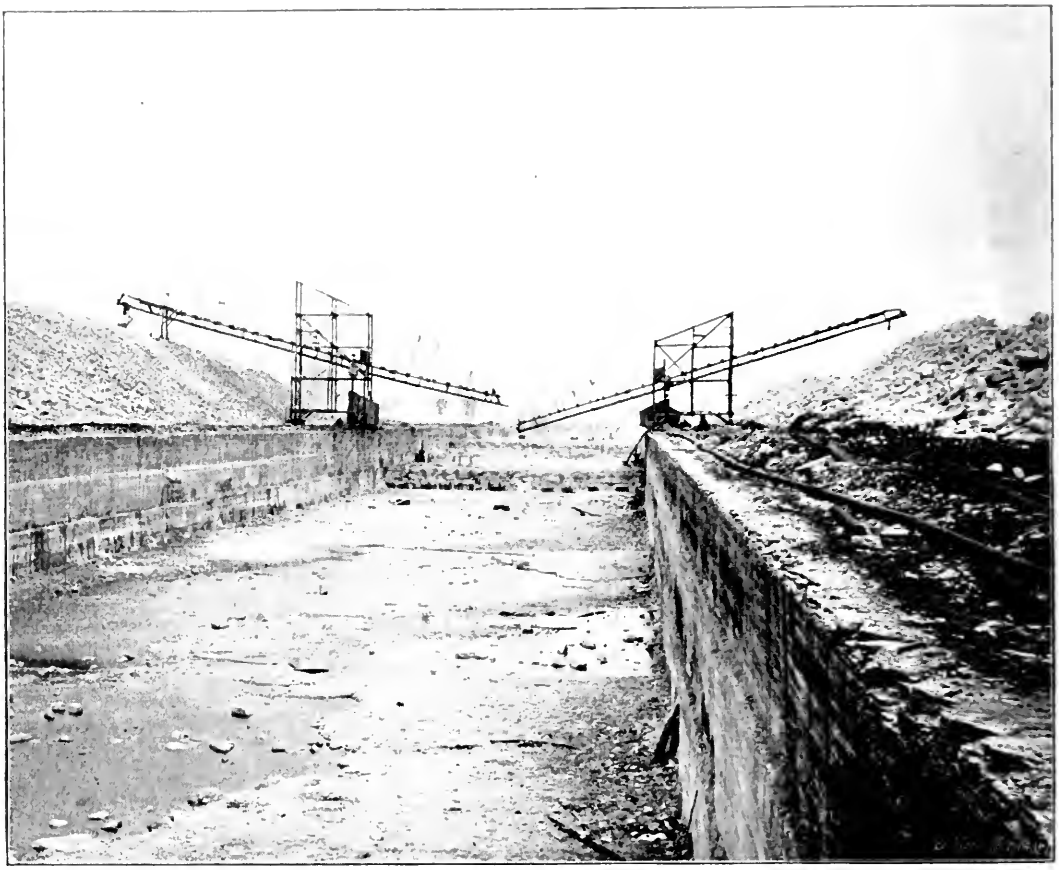


FIG. 70. GENERAL VIEW OF HULETT DERRICKS OPERATING IN FULL WIDTH OF CHANNEL ON SECTION 7.

from the engine are two other lines which may be lowered to the pit. Each of these lines, one being near the end of the boom and one near the middle, has its separate drum on the hoisting engine, and to each may be attached a bucket or skip. Thus while two buckets are being raised, two more are being automatically dumped over the spoil bank. About twelve buckets are in use at one time for two derricks, with a force of four or five men to a bucket. The working face is usually diagonal or curved. .

The cost of these derricks is approximately $16,000.

Further information with illustrations may be found in Engineering News, September 26th, 1895, and in Railway Review, October 6th, 1894.

ST. PAUL DERRICKS.

On the same Section—14—still another form of derrick is used (Fig. 71). This is a stationary double derrick made by the American Hoist and Derrick Co. of St. Paul. Two of these are in use. Each consists of a vertical mast 130 feet high, and two booms each 120 feet long, on opposite sides of a fixed horizontal wheel. Both mast and booms are made of steel channel beams latticed and connected by splice plates. Lines for raising and lowering the booms run from each to the top of the mast, and then down through the

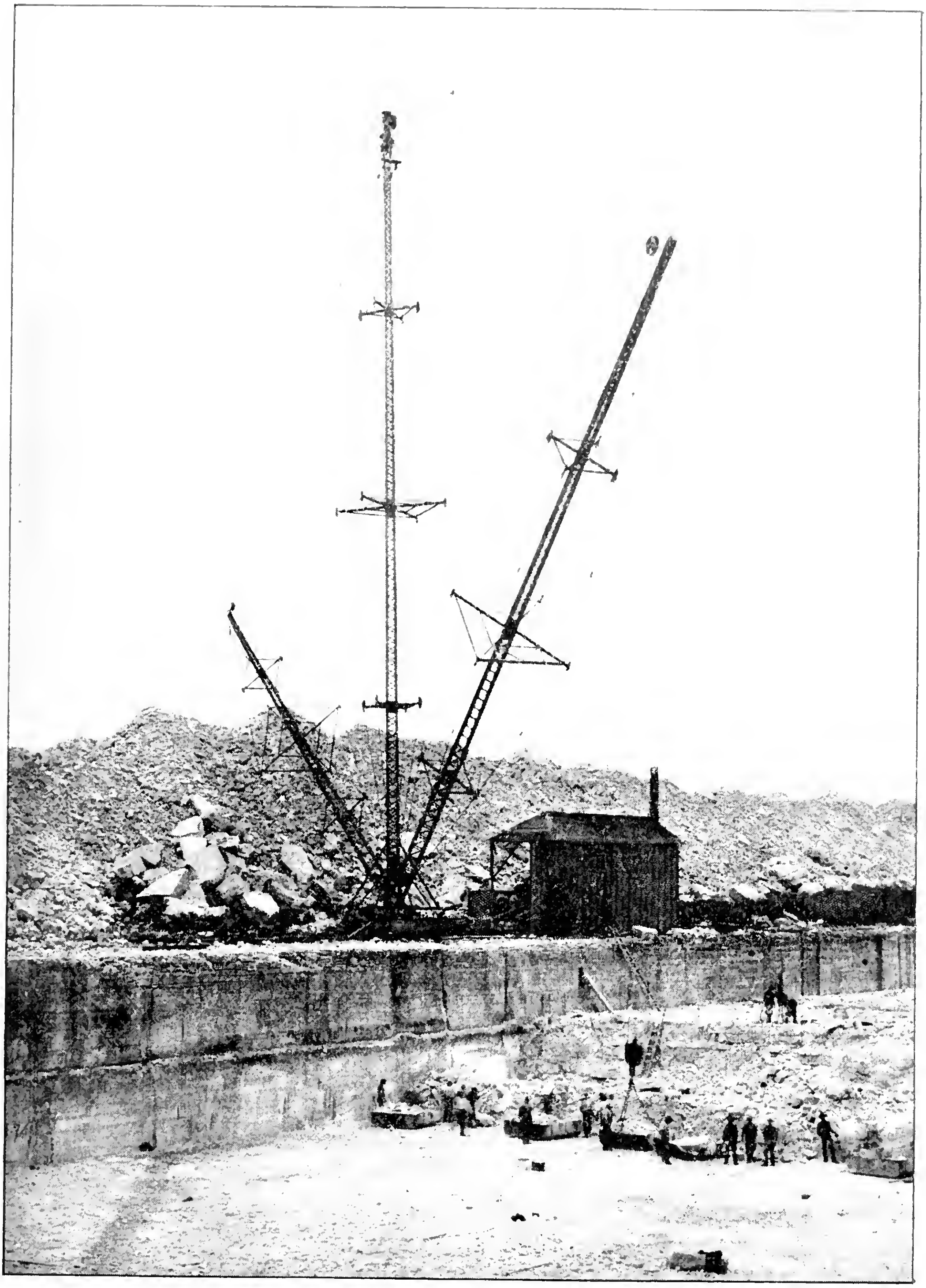


FIG. 71. THE GUYED DERRICK USED ON SECTION 14.

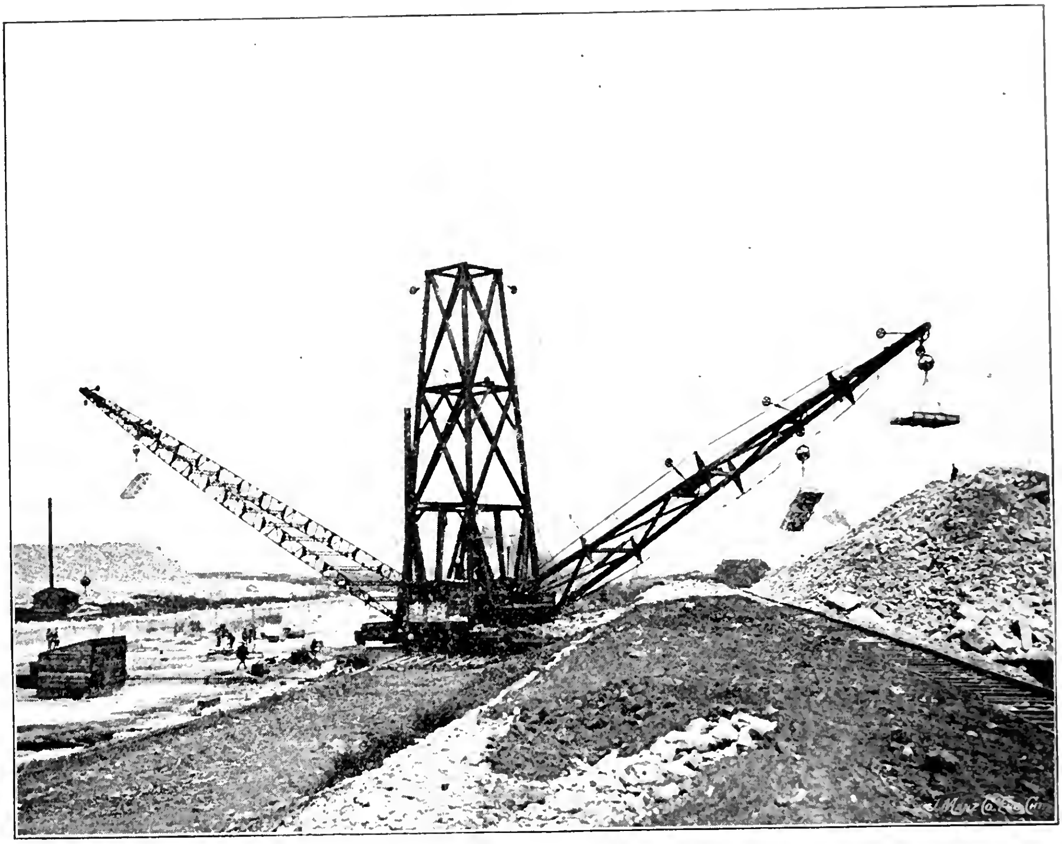


Fig. 72. Revolving Derrick Used on Section 14.

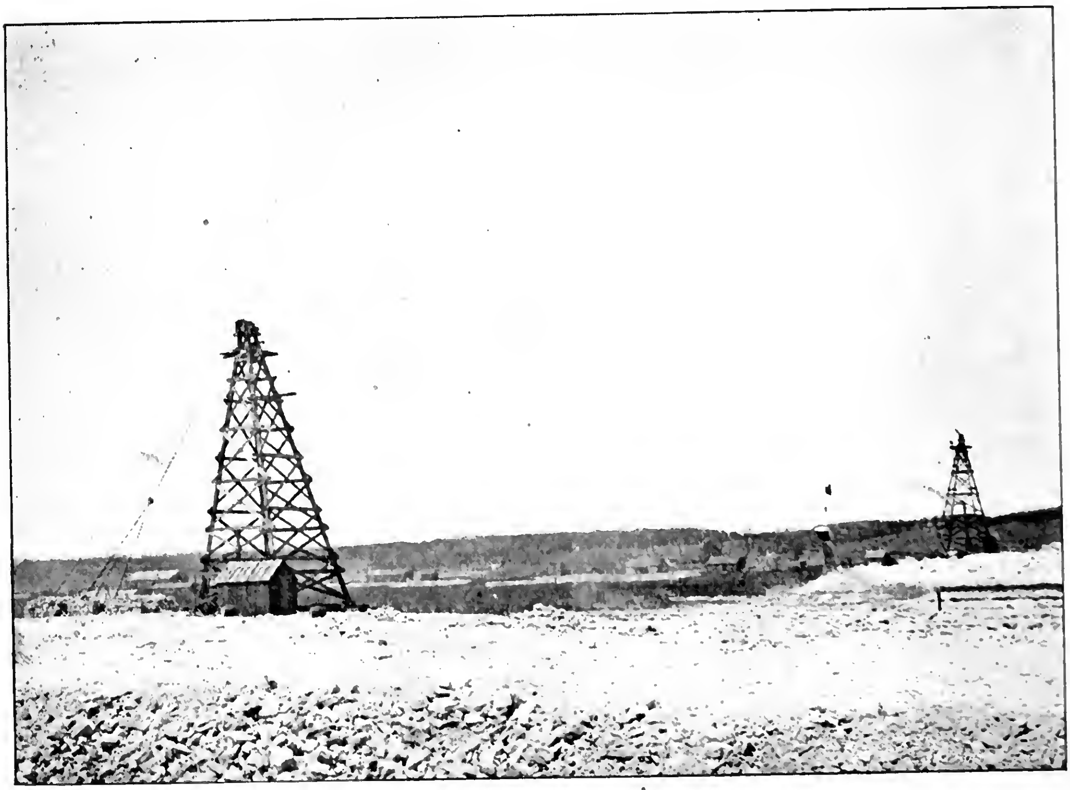


Fig. 73. General View of Cable Hoist Conveyor—Showing Skip Being Dumped by Use of Aerial Dump.

latter to the ground and to the engine, which is separate from the derrick.

One bucket is used on each boom. In operation the derricks are guyed opposite each other; a guy also passes from one to the other. The force and method of loading corresponds to those used by the double derrick, except that the working force is at right angles to the center line. While these derricks are merely large sized quarry derricks, they still do fair work considering their cost, which is only about $5,000 each.

Further information with illustrations may be found in Engineering News, September 26th, 1895, and in Railway Review, October 6th, 1894.

LIDGERWOOD CABLEWAY.

This conveyor (Fig. 73), of which twenty are now in use in rock excavation, consists of two high towers, connected by several cables of about 700 feet span, by means of which buckets are raised from the pit and dumped over the spoil bank. The "tail" tower, 70 feet high, is located close to the channel, while the other, the "head" tower, 90 feet high, containing the 50 H. P. engine, is beyond both the channel and the spoil bank.

Both towers and anchorages for the main cable are built on trucks running on tracks parallel with the canal, so that the cableway is a traveling conveyor.

There are five cables or ropes stretching between the towers. First, the main $2\frac{1}{2}$-inch steel cable which passes over both towers and to its anchorages. Second is the "traversing" or endless cable. This being attached to the "carriage" passes over the tail tower, back to the head tower, over a 54-inch drum, and back to the carriage. Thus by reversing the drum the carriage and bucket passes either way. Third, the fall rope, by which the bucket is raised or lowered. Fourth, the button rope. This rope holds at certain places little buttons of peculiar shape, which varying in size determine the location of their corresponding carriers; these being supported by the main cable serve to hold the various ropes from sagging too much. In moving towards the head tower, the carriage picks up each of these carriers on a projecting arm. In returning, each carrier continues on the carriage until it reaches its own button, which it cannot pass on account of its shape. Therefore it falls off the arm and resumes its duties of holding the ropes in place. Fifth, a rope for automatically dumping the load, which is a new contrivance, and is carried on the same drum as the traversing rope. It is attached to the back of the bucket, which is made open in front. As the bucket approaches the dumping place this rope is thrown on a portion of the drum of larger diameter. As a result the bucket turns up and the rock slides out the front.

The life of a main cable is estimated at from 50,000 to 80,000 cubic yards, while some cables have lasted longer.

The engine used on the cableway is located in a house built on the trucks under the head tower. As the spoil bank lies between this and the channel, cutting off vision, all movements of carriage or

bucket are made by signal given from the pit by means of wires and electricity.

Eight buckets are used at each working face with a pit force of 1 foreman, 1 water boy and 40 to 45 laborers.

The buckets in use are made of steel and in size are 7 feet 8 inches square, and two feet high. One side is left open to facilitate loading and dumping. A full bucket means 3.6 cubic yards water measure, or about two cubic yards of rock in place. Actual measurement, however, shows that the buckets are not loaded usually heavier than one and six-tenths cubic yards.

One great advantage of the cableway is the fact that large pieces of rock may be lifted by means of hook and chain, and deposited on the spoil bank. Thus "block holing" is largely avoided. Rocks weighing as much as seven tons are removed without difficulty. Another great advantage is its low first cost, which is only $14,000 as compared with $26,000 for the cantilever.

One prominent disadvantage is the increased danger to workmen due to the swinging and swaying of the bucket in air. Another is the item of repairs, which rapidly increases after a certain time.

Further information with illustrations may be found in Engineering News, August 8th, et seq., and Railway Review, July 25th, 1894, et seq.

CANTILEVER DERRICK.

The cantilever derrick (Fig. 65), of which eleven are in use on Sections 10, 11, 12 and 13, is a conveyor entirely new to canal excavation. It consists of a truss inclined at an angle of 12 degrees 50 minutes with the horizontal, and supported by a traveling tower. This tower is formed by two pairs of iron posts, each being 13 feet 6 inches from the center of the truss. One pair of posts is 53 feet high and the other 60 feet 8 inches. The base of this tower, framed and enclosed, forms the engine room. The tower and cantilever are mounted on four four-wheeled trucks of 4 feet 8½ inches gauge, running on two tracks parallel to the line of canal and 37 feet between centers. The center of tower and cantilever is 29 feet 6 inches from the edge of the excavation, thus bringing the nearest post 11 feet from the edge. The truss itself has a total length of 355 feet with a width of 3 feet at each end, increasing to 16 feet at points of support. In height, it reaches 30 feet between supporting posts, decreasing on each side to about one foot at each end. Two cables are in use; one for lifting the bucket, and another for raising it along the truss. The lower part of the cantilever extends almost across the canal, and is only about 20 feet above the original surface of the ground. The upper end is 93 feet 8 inches above the same.

Three different motions are used and controlled by three levers. One lever hoists the bucket from pit to truss; another transfers it to the other cable and raises it along the truss till striking the trip it automatically dumps and then returns to the pit, and a third lever moves the whole derrick along the track. Buckets can be lowered at any point on the truss and the trip can be placed at any point

on the upper arm. The average speed of cantilever along the tracks is about 150 feet per minute, but as much as 400 feet per minute has been made. The total weight of truss, tower, 120 H. P. boiler and $10\frac{1}{2}$x12 inch cylinder engine is about 150 tons. The buckets used are of iron and steel, containing 75 cubic feet water measure. The records of different cantilevers for long periods of time, show the actual working load to be from 1.5 to 1.7 cubic yards in place measurement. The best average by cantilevers was made in September, 1894, when the two cantilevers in use on Section 11 carried 627 cubic yards per day in a total of 49 days worked. For comparison, the yardage per day of all the cantilevers in use is given below.

The time period on Section 10 is from January 1st, 1894, to February 1st, 1895, while the others are all from February 1st, 1894, to February 1st, 1895.

Section.	No. Machines.	No. Days. (10 hours.)	Yds. per Day.
10............	3	928.5	477.9
11............	2	599.2	494.6
12............	2 to 4	684.5	489.1
13............	4 to 2	1,006.0	472.2

Figures for Sections 11, 12 and 13 are taken from Engineering News, September 10th, 1895.

In loading, nine buckets are in use with each machine, and usually five laborers to a bucket.

Further information with illustrations may be found in Engineering News, September 12th, 1895, et seq., and in Railway Review, September 8th, 1894, et seq.

COMPARISON OF COST AND EFFICIENCY.

In this article the methods of excavation previously described will be compared by tabulations and by a graphic representation of the same, Fig. 51, regarding three principal features: First, the cost of excavation; second, the efficiency of the conveyors, and third, the efficiency of pit labor connected with those conveyors.

Previous to the tabulations the following explanations will be given regarding the items included.

TABULATION XXV.—COST OF EXCAVATION.

All items of days worked and all rates of pay are from Sanitary District records. Time is reduced to 10-hour days in all cases, and delays of over one hour have been deducted. All items of "Cubic yards moved" are compiled from the monthly approximate estimates of Sanitary District engineers. The time period in each case was the longest available reliable period. Cost of work does not include first cost of machines or interest on capital invested. Also it includes only those repairs of machinery made on the ground.

CHANNELING.—The cost of channeling is figured independently of excavation. From the monthly estimate of channeling the cost per square foot is computed and the average width being 161 feet, one square foot of channeled surface practically corresponds to three cubic yards of excavation. Therefore the cost per square

TABLE XXV.
COST OF EXCAVATION IN CENTS PER CUBIC YARD.

MACHINE.	SECTION.	TIME PERIOD.	CU. YDS. MOVED.	CHANNELING.	DRILLING.	EXPLODING	GENERAL.	PUMPING.	OPERATING CONVEYOR.	PIT FORCE.	DUMP FORCE.	TOTAL COST.
Cantilevers....	10	Aug. 1, 1894–Feb. 1, 1895.	222,505	3.94	4.05	8.04	3.21	0.94	3.58	14.56	0.00	38.32
Cableways....	8	Aug. 1, 1894–April 1, 1895.	341,175	3.70	3.80	8.36	2.73	1.02	3.56	15.61	0.00	38.78
Hulett Derricks	7	Aug. 1, 1894–April 1, 1895.	87,884	3.92	4.02	7.37	2.50	1.81	5.30	18.32	0.00	43.21
Hulett Cantilevers.	7	Sept. 1, 1894–April 1, 1895.	51,851	3.92	4.34	7.47	3.45	1.81	5.50	18.25	0.00	44.74
Hulett Conveyors.	9	Aug. 1, 1894–Feb. 1, 1895..	95,942	4.05	3.75	8.47	3.81	1.23	6.22	21.39	0.00	48.92
Car Hoists....	8	Aug. 1, 1894–Feb. 1, 1895..	37,504	3.70	3.89	9.11	2.72	0.76	3.09	24.79	15.0	53.12
Car Hoists....	10	Aug. 1, 1894–Dec. 1, 1894..	60,341	3.94	3.61	8.94	3.21	0.94	1.24	22.90	2.27	47.08
Car Hoists....	9	Aug. 1, 1894–Feb. 1, 1895..	249,658	4.65	4.99	10.68	3.11	1.22	1.24	25.40	4.76	56.45

TABLE XXVI.
EFFICIENCY OF CONVEYORS.

MACHINE.	SECTION.	TIME PERIOD.	NO. DAYS (10 HOURS.)	CU. YDS. MOVED.	CU YDS. PER DAY.
Cantilever....	10	Jan. 1, 1894–Feb. 1, 1895..	928.5	443,750	477.9
Cableway.....	8	July 1, 1894–Sept. 1, 1895.	1513.8	600,725	396.8
Hulett Derrick.	7	July 1, 1894–Sept. 1, 1895.	832.3	180,406	216.8
Hulett Cantilever	7	Sept. 1, 1894–Sept. 1, 1895.	465.1	109,397	235.2
Hulett Conveyor	9	Jan. 1, 1894–Feb. 1, 1895.	533.0	178,839	335.5
Car Hoist.....	8	April 1, 1894–Feb. 1, 1895..	462.7	131,674	284.6
Car Hoist....	10	Aug. 1, 1894–Dec. 1, 1894..	224.4	60,341	268.9
Car Hoist.....	9	June 1, 1894–Feb. 1, 1895..	666.2	308,531	463.1
Double Derrick.	14	Jan. 1, 1895–Aug. 1, 1895..	1149.5	324,880	282.3
St. Paul Derrick.	14	Feb. 1, 1895–Aug. 1, 1895	413.9	63,760	153.4

TABLE XXVII.
EFFICIENCY OF PIT LABORERS.

WORKING WITH.	SECTION.	TIME PERIOD.	NO. DAYS. (10 HOURS.)	CU. YDS. MOVED.	CU. YDS. PER DAY.
Cantilevers....	10	Jan. 1, 1894–Feb. 1, 1895..	42482.9	443,750	10.45
Cableways....	8	July 1, 1894–Sept. 1, 1895	58620.0	600,725	10.25
Hulett Derricks	7	July 1, 1894–Sept. 1, 1895.	21171.0	180,406	8.52
Hulett Cantilevers..	7	Sept. 1, 1894–Sept. 1, 1895	11040.0	109,397	9.91
Hulett Conveyors..	9	Jan. 1, 1894–Feb. 1, 1895..	26114.3	178,839	6.85
Car Hoists....	8	Aug. 1, 1894–Feb. 1, 1895..	5391.7	37,504	6.96
Car Hoists....	10	Aug. 1, 1894–Feb. 1, 1895	8639.0	60,341	6.98
Car Hoists....	9	Aug. 1, 1894–Feb. 1, 1895..	36607.8	249,658	6.82
Double Derricks.	14	Jan. 1, 1895–Aug. 1, 1895.	47265.9	388,580	8.22
St. Paul Derricks	14	Feb. 1, 1895–Aug. 1, 1895.			

foot is divided by three and this result used as the cost per cubic yard. The men employed and the scale of wages are shown under "Channeling."

DRILLING.—The men employed are given under "Drilling."

EXPLODING.—This includes dynamite, fuses, caps and electricity, estimated altogether at 12 cents per pound of dynamite, and powdermen where used at $1.50 to $2.00 per day.

GENERAL.—This includes all superintending force, watchmen, repair and incidental forces not otherwise placed.

PUMPING.—This includes pumps actually in use and the operation of the same.

OPERATING MACHINE.—This includes engineers, firemen, conveyor men, machine foremen and signal boys.

PIT FORCE.—This includes foremen, laborers, water boys and teams used on the spoil bank.

TABULATION XXVI.—EFFICIENCY OF MACHINES.

See remarks about time and "Cubic yards moved" under Tabulation 1.

TABULATION XXVII.—EFFICIENCY OF PIT LABORERS.

"Number of Days" includes only such laborers as were actually engaged in loading cars or buckets. Delays exceeding one hour are deducted.

COMPARISON OF CONVEYORS.

In reaching any conclusion as to the efficiency or relative value of the machines used, there are several items to be considered. First, cost, maintenance, liability to accident or delay, and final value of plant should all have their weight, as well as the rapidity and actual cost of conveyance of material.

Of all the methods of conveying material above described, only one was used to any large extent before the construction of this channel began. All the others had their birthplace practically on this work. The one exception is that of Car Hoists, and this, while not by any means new to excavation, has been greatly improved.

In the writer's judgment the battle for supremacy lies between the cantilever crane and the cableway with the car hoists as used on Section 9, third.

The cantilever costs $28,000, and the cableway $13,000. Maintenance and repairs cost very little on either at first, but with time they increase far more rapidly on the cableway. Accidents to laborers have proven more frequent with the cableway because of the swaying buckets. The records show that for smoothness and regularity of operation, and for absence of small delays, the cantilever is the better. According to the tabulation shown herewith, the actual cost of excavation is slightly in favor of the cantilever, the yardage per day considerably so, and the yardage per laborer also slight-

ly favoring the same machine. Both machines will probably have to be reconstructed to be of service after completing this work. Therefore for these reasons the cantilever would seem to be the most preferable machine in use. If time were not an important consideration and capital invested were, the cableway would seem most preferable, especially so if the contract were not one of extreme magnitude.

Next to these two conveyors, in the writer's opinion, would come the car hoist methods as above described and used on Section 9. While the actual cost of excavation has been higher than other methods, the first cost was comparatively very low, very little experimenting was necessary and the entire plant can be turned over to other work when this is finished.

The comparison of first cost, yardage and operation, of all methods above described, is given in the following table derived from the foregoing comparison sheet. In this table the item "Operation," includes operation of machine, pit labor and dump labor.

TABLE XXVIII.—COMPARISON OF CONVEYORS.

	First cost.	Operation cts. per cubic yd.	Yardage per day.
Cantilever	$28,000	18.18	478
Cableway	13,000	19.17	397
Hulett Derrick	10,000	23.62	217
Hulett Cantilever	15,000	23.75	235
Hulett Conveyor	25,000	27.61	336
Car Hoist (1)	3,000	32.94	285
Car Hoist (2)	3,000	26.41	269
Car Hoist (3)	4,000	32.40	463
Double Derrick	16,000	.....	282
St. Paul Derrick	6,000	.....	153

DISCUSSION.

Mr. Thomas T. Johnston: Mr. Potter's instructive paper suggests that a brief statement with reference to the development of conveying and excavating machinery on the rock work of the Sanitary and Ship Canal may be of interest.

Contracts for fourteen miles of the works, aggregating about $12,000,000 in value, were let in June, 1892. Nearly all of the site of the work was under water between the time of inviting and receiving proposals for the work, which fact, in connection with subsequent developments, leads to the conclusion that at the time of making proposals, none of the bidders had more than a vague idea as to how they would do the work. This part of the work comprised Sections 1 to 14 inclusive (see map, Fig. 49), of the Main Channel work and as a matter of fact, the contracts for ten out of the fourteen sections were afterward abandoned by the contractors, but in only four of the sections was the price for the work afterward increased.

The contracts having been secured, the preliminary to actual work occurred September 3d, 1892, when Mr. L. E. Cooley pushed the button that resulted in the first blast of rock and Mr. Wm. Boldenweck dug the first earth with an ordinary shovel. Work was then undertaken with such crude appliances as seemed to be most handy. Where there was but little earth, or very soft earth, wheelbarrows and shovels were used; when there was enough earth and that sufficiently hard, wheel and drag scrapers were used; where the earth was very hard, as it was in several places, steam shovels were put to work, only to abandon the work later because the price for it was too little, and because the type of machine at hand seemed hardly equal to the occasion; where rock was excavated the mule and cart, the tram car and incline hoist were adopted as conveyors.

It was not until the spring of 1893 that there were any signs of the magnificent plants, which have since become so well known. Meantime, contracts were let for Sections A to F inclusive (see map, Fig. 49), constituting six sections, aggregating six miles in length, the bidders benefiting little or nothing by the experience of the contractors for Sections 1 to 14. In November, 1893, Sections G to M inclusive were let comprising another five miles of the work, the bids being made in the light of the experience of the season's work. These six sections were divided equally between three contractors, all of whom adopted methods entirely unlike and radically different from anything used on the twenty miles of work previously under contract. Sections N and O were let in May, 1894 (see map); the work, unlike any other work on the line, to be done by dredging. Section 15, the last of all, and an all rock section, was let in August, 1894, and in the light of nearly two years' experience in rock work on the older contracts, a radically different mode of work was adopted. Generally speaking, where the contractors for any one section on the line benefited by the experience on older contracts, it

resulted in the adoption of a new departure in mode of working. The exceptions are few and not worth dwelling on at this time. The net result is that no stereotyped method of working has been developed. The inventive genius of the contractors or those serving them seems to be as yet unbounded. This is particularly true of those having earth excavation to do, and indicates that when the next huge work of excavation is undertaken there may be expected as radical an improvement in methods as has been witnessed on the Chicago Canal.

The excavating appliances used may be, in general, classified as those pertaining to earth and to rock, the latter being those in part considered by Mr. Potter. The rock working appliances may, in the main, be divided as follows:

(1) Channeling machines.
(2) Drills:
  (a) Hand.
  (b) Steam.
  (c) Air.
(3) Disintegrating agencies.
(4) Loading devices.
  (a) Manual labor.
  (b) Steam shovel.
  (c) Air hoist.
(5) Conveyors.
  (a) Teams with carts or wagons.
  (b) Incline hoists with tram cars.
  (c) Brown cantilever conveyor.
  (d) Cable hoist conveyors.
  (e) "High Power" derricks and incline conveyors.
  (f) Revolving balanced derricks.
  (g) Guyed boom derricks.
  (h) Cars and locomotives.
  (i) Hulett cantilevers.
  (k) McMyler revolving boom derricks.
  (l) Air hoist with modified Heidenreich incline.
(6) Air compressors.
(7) Appliances pertaining to retaining walls.

CHANNELING MACHINES.—The contracts for rock excavation in the main channel all require that the sides of channel be formed by use of a channeling machine (see Fig. 51), and that where the thickness of the rock is sufficient, the depth of the cut made by the machine shall not be less than twelve (12) feet. This was a decidedly experimental feature when it is considered that the rock is often of a very friable structure and always stratified, the thickness of strata being in general one or two feet, though sometimes several feet. Furthermore, the rock is far from homogeneous in structure, an element operating to prevent the tool making a truly vertical cut; in other words, causing the tool to take a lateral movement and cutting a surface with curvilinear rather than rectilinear

elements. The tool, it must be understood, is a flat metal bar about 1x6 inches in cross-section. The tool is raised and lowered similar to the tool in a percussion drill and the whole machine moves back and forth in a right line. The result is a slot (Fig. 52) cut in the rock on the line of the side of the excavation, separating the rock to be excavated from the rock to be left in place. For various reasons the depth of any cut or slot has rarely exceeded twelve feet. In a hard, homogeneous rock the slot cut should have a width not much different from one and one-half inches, but the rock is frequently so friable that the width of slot amounts to several inches. The little fragments of rock dropping to the bottom of the slot from its walls are more or less a source of annoyance. The general nature and construction of the machines have not been materially changed during the progress of the work, though there have been minor modifications. It is sufficient to say that the experiment has been radically successful, as is evidenced by the smooth and neat appearance of the work done, as shown by the illustrations.

DRILLS.—Little has developed in drilling machines. (Fig. 52.) In the river diversion work where the depth of rock was but a foot or two, hand drilling was done at some places. Where the rock was thicker, as in the main channel and in block holing, where power was convenient, percussion drills have been used, driven either by steam or air. The main body of the work done has required holes approximating twelve feet in depth.

DISINTEGRATING AGENCIES.—In certain shallow excavations when the rock was in sufficiently thin layers the rock has been "barred" by the use of crow bars and manual labor, but generally the work has been done by means of low-grade dynamite. Fig. 53 shows an example.

LOADING DEVICES.—The rock having been disintegrated, the problem of delivering it to a conveying device has been of a more or less perplexing nature. To load into a tram car by manual labor has required the lifting of stones through several feet. To load into a flat bottom skip or box, the bottom being close to the ground, has involved less physical effort. These have been the extremes of conditions met. The nature of skips in use has varied with the several machines, according to the construction of the machine, so that the best solution of the problem involves many considerations beyond the mere act of loading.

In Section 15, where the conveying has been done in cars on standard gauge track, hauled by locomotives, ordinary heavy steam shovels (Figs. 55 and 57) have been used to load the cars. This process has required the use of more than the ordinary amount of drilling and explosives to reduce the stone to proper size, but has saved a great deal of manual labor. The result has been very satisfactory. The shovel has been worked in general on a face about twelve feet high.

One difficulty met in loading by manual labor and steam shovel has been due to the breaking of stone when blasted so as to leave a

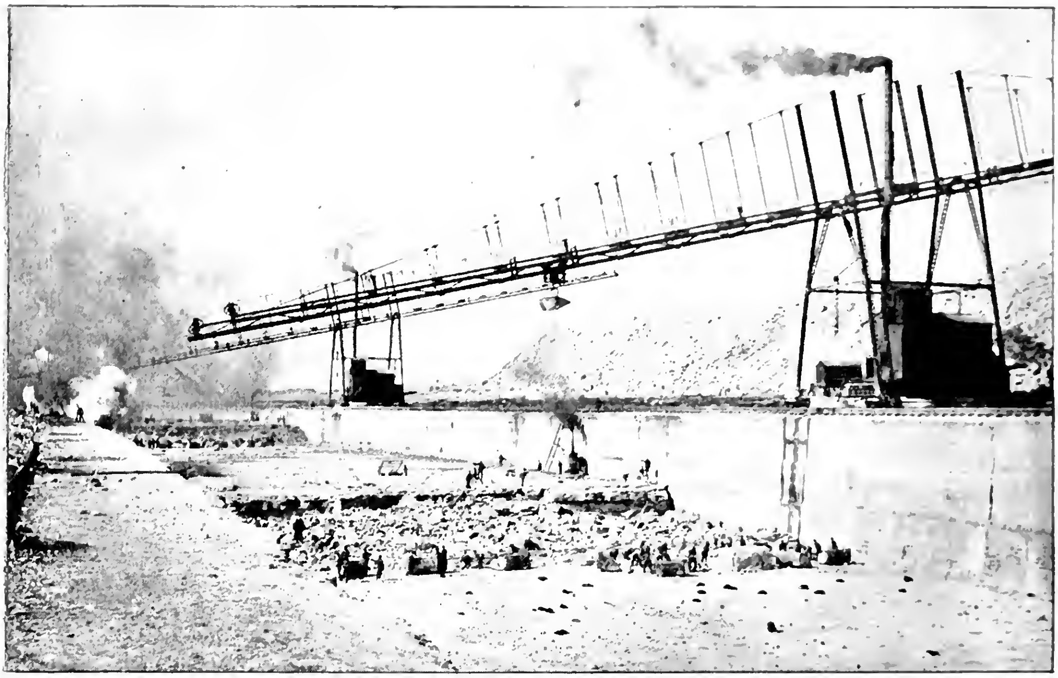


FIG. 74. THE BROWN CANTILEVER CONVEYOR, SHOWING ARRANGEMENT OF SKIP AT FACE; ALSO CHANNELING MACHINE AT WORK ON TOP OF SLOPE AT CENTER OF VIEW.

number of stone too large to be easily handled, thus requiring breaking up by use of sledge hammers or block holing. When rock excavation was commenced in Section 1, which was in 1894, long after satisfactory modes of work had been developed in other sections, an effort was made to install an improved method (Fig. 56). The conveying was to be done in a small and low tram car, the top being less than three feet from the ground. A device was made to load the larger pieces of stone into the tram car, the smaller pieces being loaded by manual labor. This device comprised: First, a horizontal boom swinging over the site of loading at a height of about twenty feet. Traveling back and forth on the boom was an iron cylinder suspended vertically. In the cylinder was a piston with a rod extending downward. The piston was caused to travel in the cylinder by means of compressed air. The lower extremity of the piston rod carried a grapple to take hold of the larger stone, which were raised when the air was allowed to enter the cylinder. Having been raised to a sufficient height the boom was swung until the stone was over a tram car, when it was lowered to the car. The device, in conjunction with other details involved in the appliance, proved unsatisfactory and was abandoned.

CONVEYORS.—The most extensive development has taken place in conveyors, the earlier forms of which consisted simply of teams and carts or wagons, followed closely by the use of tram cars hauled by cable to the top of a trestle on an inclined track, the cars being dumped from the trestle (Figs. 58, 59, 60, 62, 63, 67). These methods only were used until early in 1893, when the cable hoist

(Fig. 74), and the Brown cantilever conveyors (Figs. 65, 66), were simultaneously introduced, the former on Section 11, and the latter on Section 13. One of the latter was at about the same time installed in Section 10, but was not put in operation until later. It is an interesting fact that while every other form of conveyor was installed later, none of them proved so satisfactory. The history of these appliances may be followed independently.

The Brown cantilever (Figs. 65, 66), in operation on Section 13, was destroyed through carelessness during a heavy windstorm in April, 1893, after having operated but a short time, and at the expense of several lives. The machine was mounted on a track along which it traveled parallel to the axis of the channel by its own motive power. At the time of the storm it was not properly fastened to the track with the result that the wind set it in motion until it had traveled to the end of the track, which point being reached the machine overturned and was completely wrecked. This accident did not prevent the construction of three of the machines on Section 10, all of which were put in operation in the summer of 1893. In the fall of 1893 five other machines of this type were put in operation, distributed on Sections 10, 11, 12 and 13. Their performance on the work has shown them to be mechanically the most desirable rock conveyors that have as yet been installed, and they would doubtless have found wider application if satisfactory arrangements could have been made with the makers as to price, or if there had been

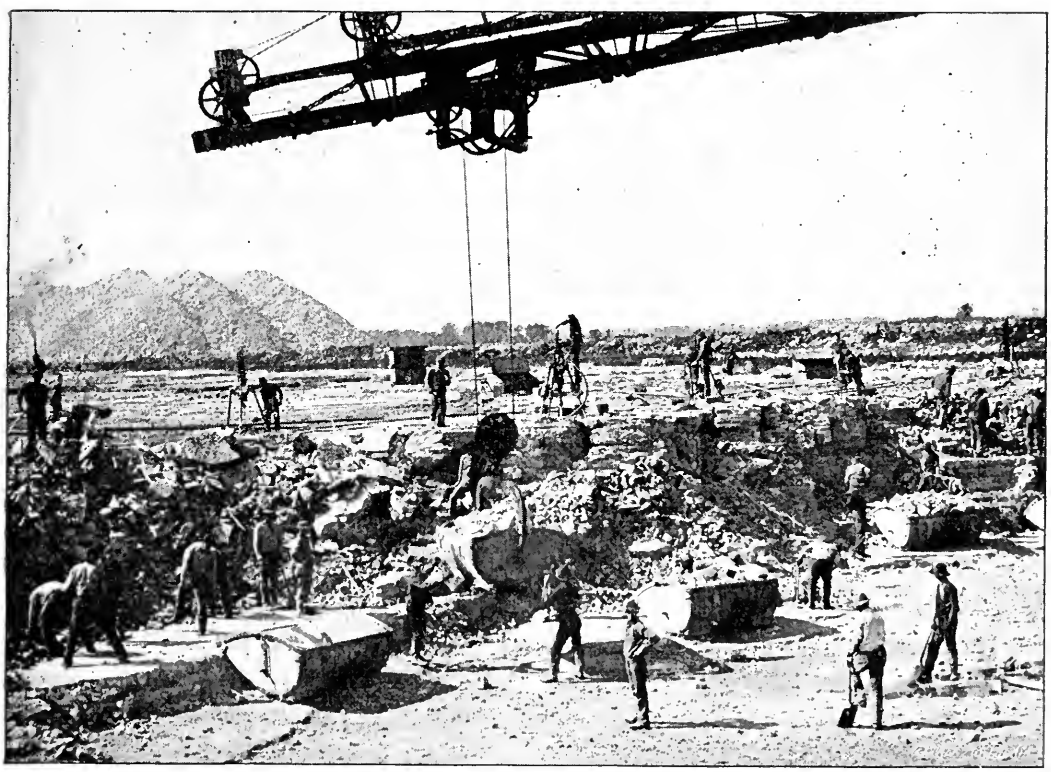


Fig. 75. Showing in Detail the Loading of Skips for the Brown Cantilever Conveyor.

FIG. 76. SHOWING ARRANGEMENT OF SKIP AT A FACE FOR THE CABLE HOIST CONVEYOR.

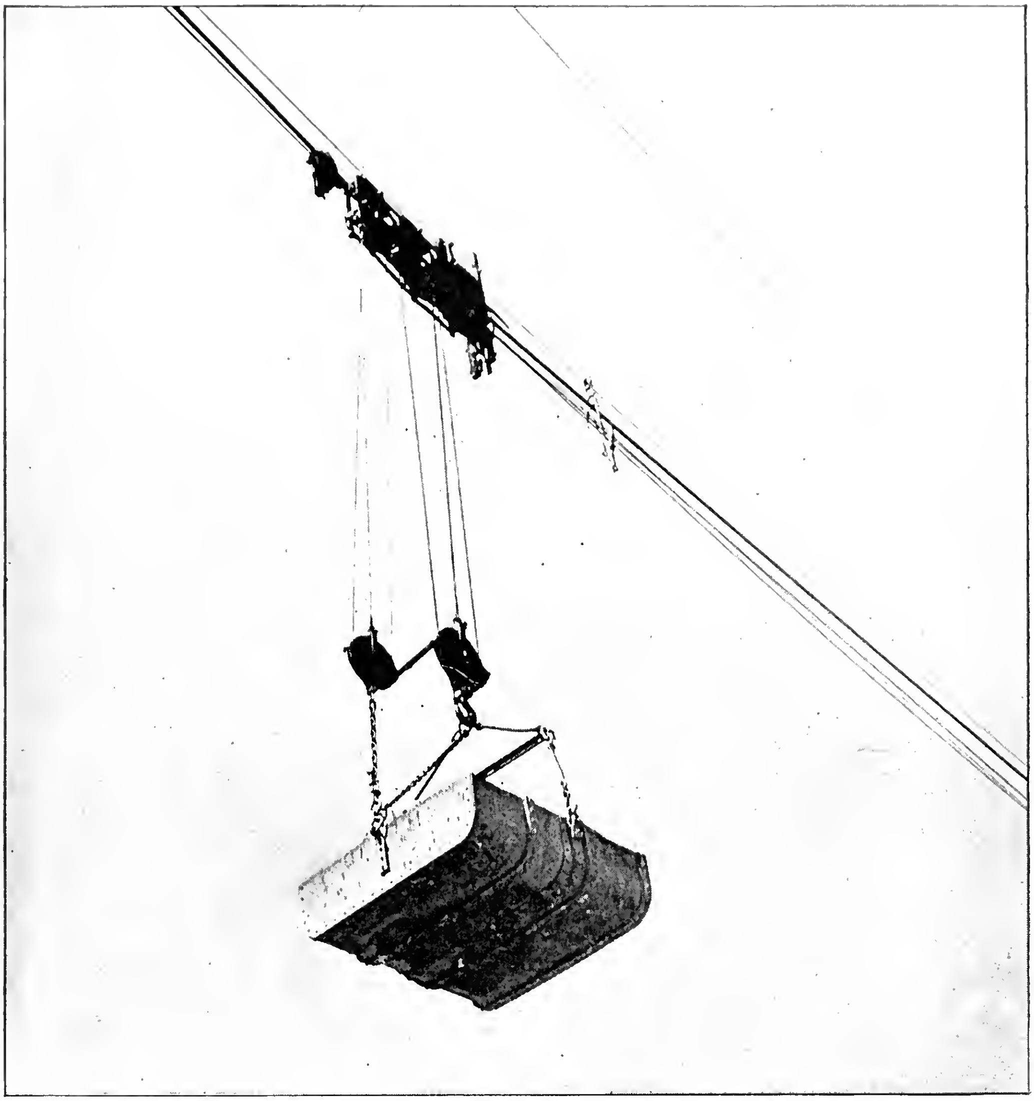


FIG. 77. SKIP FOR THE CABLE HOIST CONVEYOR, SHOWING ATTACHMENT OF "AERIAL DUMP." TACKLE AT BACK OF SKIP.

a longer period during which they could have been operated. The contract for Section 10 was completed in the summer of 1895 and two of the machines there used were sold and transferred to Section 1, where they are now at work, taking the place of the air hoist arrangement already referred to, which was abandoned. The character of these machines was not changed during the progress of the work.

The cable hoist (Figs. 64, 73, 76, 77), first applied as already stated, was installed on Section 11 and for a year or so did not promise well. It consisted of two towers at opposite sides of the channel, between the tops of which was stretched a two and one-half inch twisted cable, the length of which was some 800 feet, more or less. The skip (Fig. 77) being loaded in the pit was raised until engaged in a trolley traveling on the cable, and thence was conveyed to the

spoil bank and then lowered so that a man could loosen the proper chains. Then the skip was raised until dumped and later conveyed back to the pit. This operation proved cumbersome and resulted in many breakages and generally unsatisfactory performance. Finally, however, Mr. Locker, who had worked so persistently with the machine on Section 11, invented a device by which the skip could be made to dump its load at any time without being lowered, and thereby improved the performance of the machine to an extent that put it in successful competition with the Brown cantilever. A second machine was installed on Section 8 in the spring of 1894, which was rapidly followed by three other installations on this section, and about twenty others distributed over Sections 2 to 7 inclusive. The difference between success and failure for this machine was measured by the inexpensive contrivance invented by Mr. Locker, which has since been called the "aerial dump." The device as invented by him has since been modified somewhat, but its general nature has remained unchanged. An unsuccessful attempt to use a similar appliance was made on Section 14 in 1893, and was abandoned. Almost the same device was used in river diversion work in Section B in 1893 for conveying earth, but did not prove to be at all suitable for that class of work. It may be said for the cable hoist conveyor, in contrast with the Brown cantilever, that its possibilities have been but slightly developed on the work of the Chicago Canal, while the same can hardly be said of the cantilever. The cable is adapted for long distance conveying which the other machine is not.

The so-called "high power" derrick and incline conveyor (Fig. 61) was installed on Sections 7 and 9 in the latter part of 1893. They were conceived at the time the Brown cantilever and the cable hoist were in the experimental stage, but were not so fortunate as to results. The device consisted, first, of a revolving boom derrick mounted on a turntable, which in turn was mounted on a track, so that the machine could travel parallel to the axis of the channel by its own motive power. The track was located on the center line of the channel and was laid toward the face being excavated. The swing of the boom covered a little more than the width of the channel, which is 160 feet, thus permitting the derrick to pick up a skip loaded at any point in the width of the channel. At the side of the channel and on the boom was constructed a tower, mounted on a truck. This tower supported an incline, the lower end of which was immediately over the edge of the channel, the higher end being about 100 feet distant and over the top of the spoil bank. The tower contained the machinery which hauled a car from the foot of the incline to the top where it was dumped automatically. The skips raised by the derrick were dumped into a car at the foot of the incline. The appliances, while good, suffered in comparison with the cantilever and cable hoists, and those on Section 7 were afterwards converted into Hulett cantilevers (Figs. 68, 69 and 70) to be presently described, while those on Section 9 were operated as originally constructed until that section was completed.

Early in 1894 Section 14 had passed into the hands of new contractors, who found the section without any plant. They set about devising a plant radically different from anything developed by the experience of 1893. The result was a huge revolving boom derrick (Fig. 72) having a central tower about 100 feet high carrying two booms about 165 feet long, set 180 degrees apart, the one balancing the other. The whole was mounted on a turntable which in turn was supported on a series of wooden rollers. The appliance was set at the side of the channel on the berm. The sweep of the booms covered at once the width of the channel and the spoil banks. Ultimately four of these machines were installed in the section, two at either side of the channel. The machines did not differ materially one from another. The earlier experience with them was exceedingly discouraging on account of faulty design and it was not until after some months of experimenting, repairing, etc., that any good results were obtained, but in the spring of 1895 they were brought to a state of perfection which has entitled them to consideration as a very creditable appliance, though not so satisfactory as the cable or cantilever hoists previously used.

About the same time two guyed derricks (Fig. 71) with swinging booms a little over 100 feet long were installed at the south end of this section, but they have proved to be too slow in operation to be at all satisfactory.

Early in 1894 Section 7 passed into the hands of new contractors who found on the section two of the so-called "high power" derricks (Fig. 68) and incline conveyors already described. The arrangement being unsatisfactory they set about reconstructing them after awhile. The revolving McMyler derrick, which had been working on the center line of the channel, was removed, tracks and all, to the berm (Fig. 68), at the side of the channel, from which position the derrick would raise all skips within reach, which was to about the center of the channel, and swing them to spoil banks adjacent to the berm.

The incline conveyors were, however, radically remodeled, as indicated in Figs. 69 70. The tower supporting the incline was preserved on its tracks as before, but the incline was removed, and in its stead a truss was framed to the tower, one end of which extended over the channel to its center and the other extended to the top of the spoil banks. This truss supported a trolley which traveled from end to end. Skips loaded within reach were raised to the trolley and thence conveyed to spoil banks to be dumped automatically. The arrangement was, in general, similar to the Brown cantilever in action, though comparatively diminutive, crude and slow. The Brown machine spanned the whole width of the channel, while this appliance, which has been called the Hulett derrick, spanned but half the width of the channel.

In the latter part of 1894 the contract for Section 15 was let. This section has a varying width and one-half of it is not arranged to readily permit the use of plants previously adopted in other sec-

tions. Furthermore, the amount of rock to be excavated would operate against installing an expensive plant. The result has been to lead to the application of the steam shovel as a loading device, as already explained, and to the use of cars and locomotives (Fig. 57) for conveyors. The arrangement has proved very satisfactory.

It is worth while to note, at this time, the application of tram car and incline hoist methods (Fig. 60), on Section 9. This section in 1894 passed into the hands of a new contractor, who found therein two of the so-called "high power" derricks and incline conveyors (Fig. 72). These he operated until his work was done, but they did not accomplish much. The bulk of the work was done by use of small tram cars hauled up inclines by cable. This is the only all rock section in which this method of working was adopted for so large a share of the work. Mr. Potter has given data as to its cost.

The last of the rock-working appliances to be devised was the air hoist and incline conveyor on Section 1 (Fig. 56), and this was done in the summer of 1895. The air hoist has already been described. The tram cars were run to the face being excavated on a series of parallel tracks of narrow gauge. These tracks led away from the face until they met a track transverse to the channel. In this transverse track were turntables to permit the transfer of the tram cars from the longitudinal tracks. Finally, the transverse track led up an incline at the top of which the tram cars were dumped au-

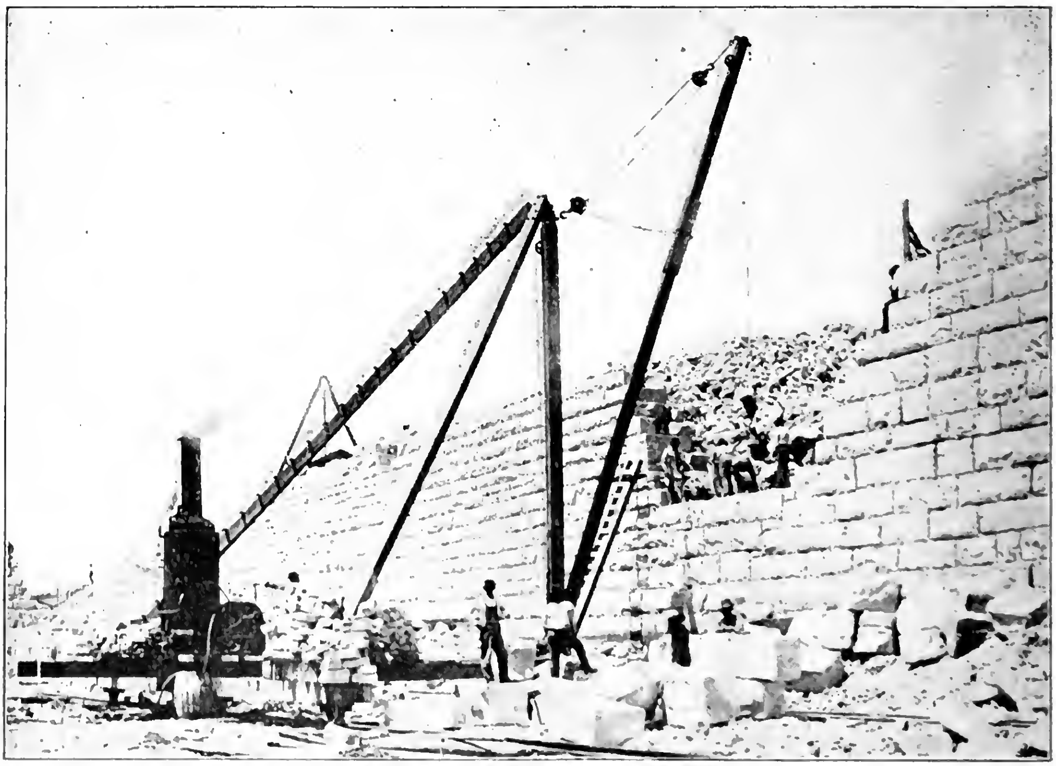


Fig. 78. Typical Wall Derrick Used during 1895.

tomatically. As previously stated this arrangement proved unsatisfactory and was abandoned. Two of the Brown cantilevers from Section 10 have been installed in its stead.

AIR COMPRESSORS.—The air compressors in use are all of ordinary types and need no discussion.

APPLIANCES PERTAINING TO RETAINING WALLS.—Various arrangements have been made for quarrying rock for retaining walls and for erecting the walls, but they are not of great moment, though in general very skillfully devised. A wall derrick is shown in Fig. 78.

Mr. Potter has analyzed the cost of excavation by the most important of the several appliances herein mentioned, and his data together with the several views of the appliances presented will doubtless create interest in the historical items herein stated.

VI.

CO-EFFICIENTS IN HYDRAULIC FORMULAE, AS DETERMINED BY FLOW MEASUREMENTS IN THE DIVERSION CHANNEL OF THE DESPLAINES RIVER FOR THE SANITARY DISTRICT OF CHICAGO.

By W. T. Keating, M. W. S. E.

Read April 1, 1896.

These measurements were made according to instructions of T. T. Johnston, assistant chief engineer of the Sanitary District, at a point opposite Gary Station, on the A. T. & S. F. R. R. (Fig. 79).

There is a stretch of about three miles of artificial channel at this point, opposite Sections A, B and C of the main drainage channel. The river diversion channel is 200 feet wide at the bottom, fairly level across, and straight for a considerable distance above and below the discharge section.

On the left side there is a high levee, and on the right side the natural surface slopes up quite rapidly. With about 5 feet of water in the river the 25 feet of berme on the left side is overflowed, and with 8.5 feet the water goes over the right bank. At the highest gauge measured the river was 270 feet wide. The depth of water in the channel at that time was between 9.5 and 10 feet. The bottom of the channel in the vicinity of the discharge section is in general hard and gravelly, but up under the banks and, in places, clear across the channel, there are soft places where growths of flagweed and willows flourish.

There was a growth of this kind at the section itself, but they had been cut away about eight months previous to taking the measurements and gave no trouble. Whether either the weeds or the willows within a thousand (1,000) feet of the section were of sufficient number to make any perceptible change in the roughness of the bed is doubtful.

Rod-floats were used to determine the mean velocity, the immersion being usually about nine-tenths of the depth. These rod-floats, as I suppose you all know, are cylindrical pieces of wood about an inch and a half in diameter and they come in lengths of four feet or less. They are made so they can be jointed together and make a float of any desired depth or length. They have a cylindrical perforated tube at the bottom, which is filled with shot or little scraps of iron or anything that will weigh the tube down and make it sink to the desired immersion. It is desirable to have the immersion as nearly equal to the depth as possible.

The floats were timed upon a base 100 feet long laid out parallel to the river on the levee side. Three ranges were laid out, at right angles to the base, one at each end and one in the middle,

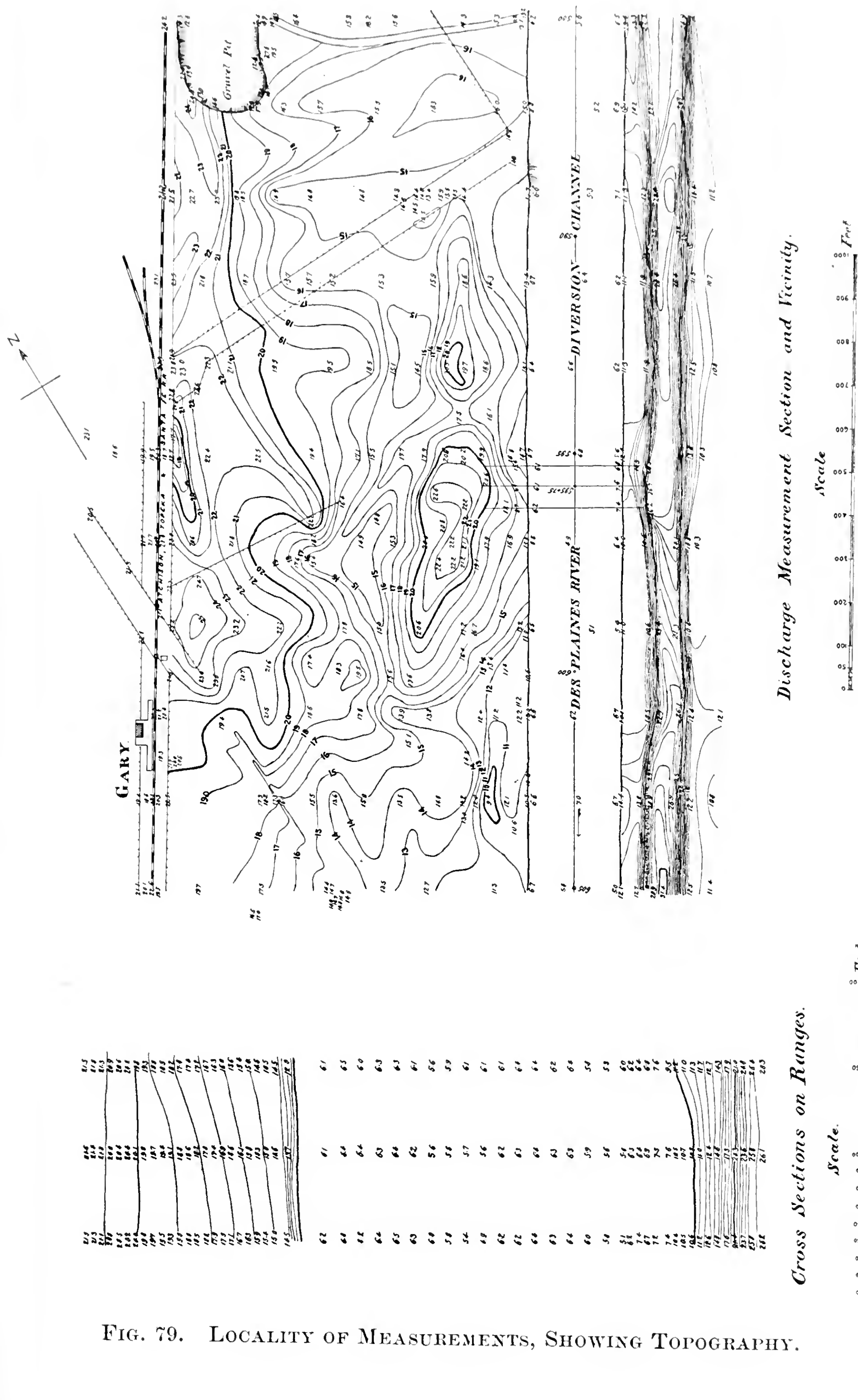


FIG. 79. LOCALITY OF MEASUREMENTS, SHOWING TOPOGRAPHY.

Distance in feet.

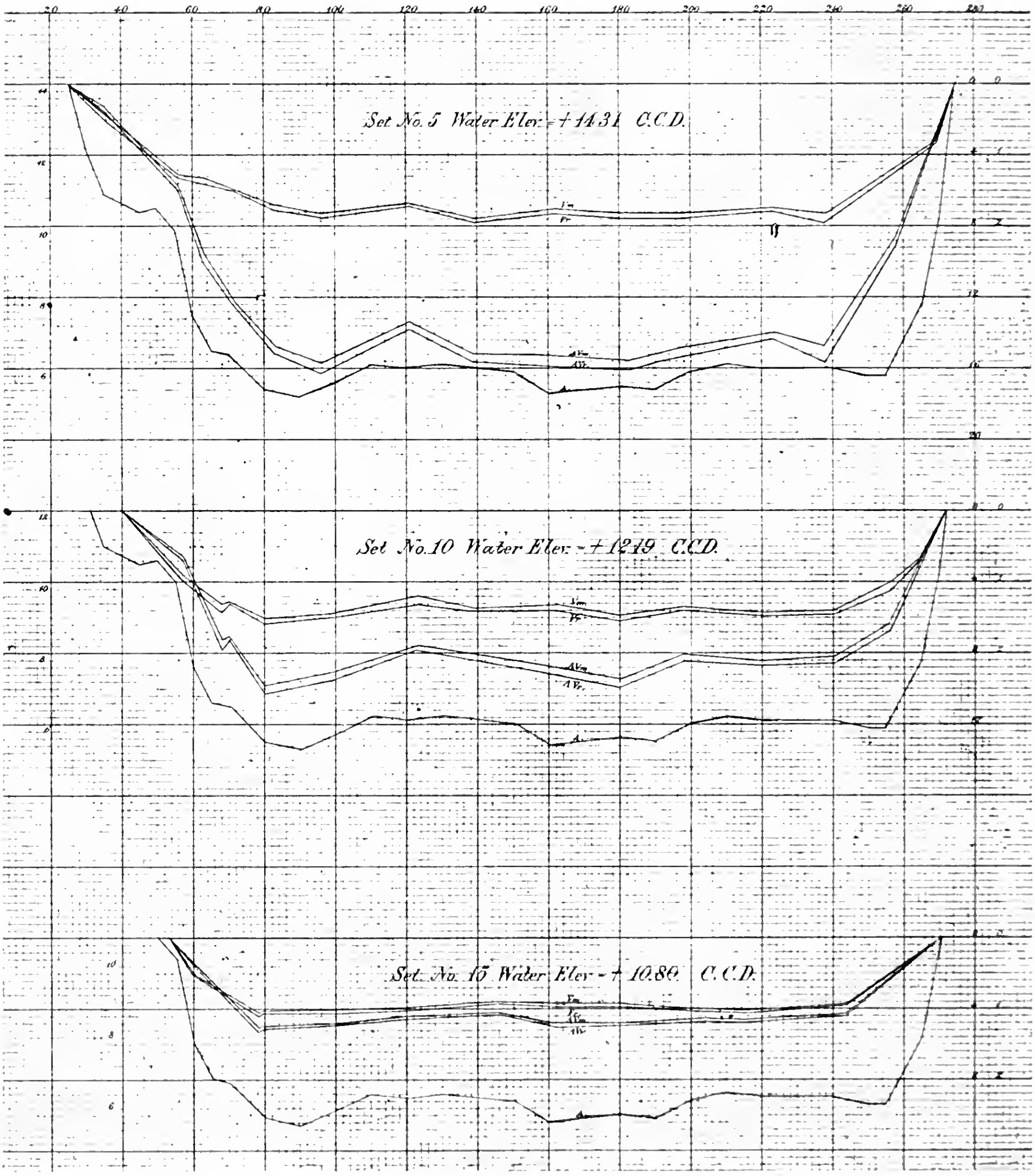


FIG. 80. AREA, VELOCITY AND DISCHARGE.
(Individual Sets).

Distance in feet.

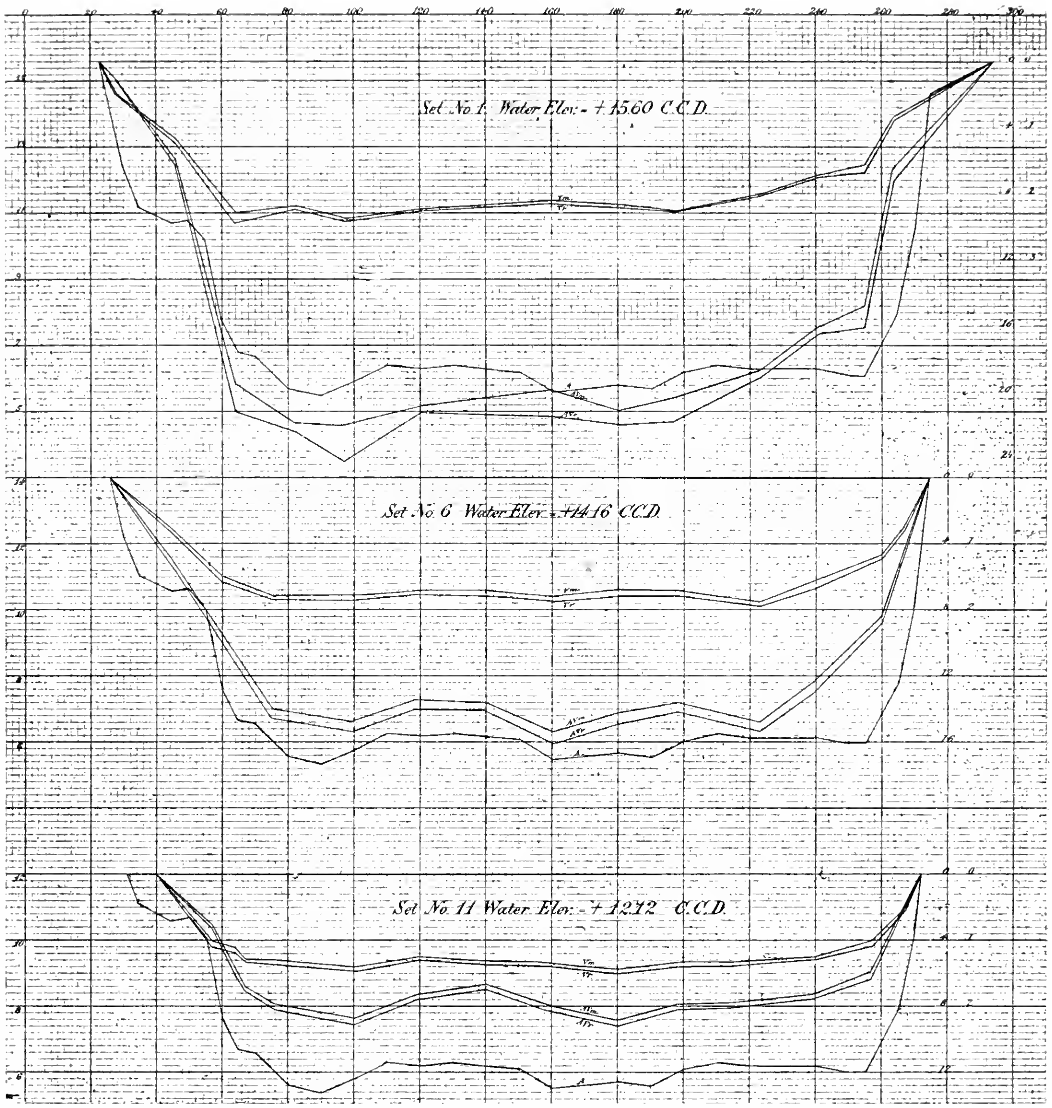


FIG. 81. AREA, VELOCITY AND DISCHARGE.
(Individual Sets.)

called respectively, upper, middle and lower ranges. The floats were started on an auxiliary range 30 feet above the upper range, the distance out being known by tags on a wire cable stretched across the river. The wire cable we used was one-eighth of an inch in diameter and graduated under a tension. We hung it between two telegraph poles and we gave it about the tension we thought it should have in hanging across the river and graduated it that way, and we found it was almost as good as a steel tape; the different lengths being located by angles were found to be within a couple of tenths or so of being the correct distance. The floats were timed by a stop-watch, the nearest half-second being noted. They were located on the middle range by horizontal angles taken from a point on the base produced 400 feet upstream from the middle range.

Floats were run every 20 feet for the full width of the channel, such series being designated a "set."

Fifteen (15) sets in all were taken, the gauge ranging from 15.6 to 10.8.

These discharges have been computed in two (2) different ways: First, using the velocities as observed, and secondly, using the observed velocities as reduced by the Francis formula, viz.:

$$Vm = Vr\left(1\ 012 - 0.116\sqrt{\frac{d'}{d}}\right)$$

In which Vm = Reduced Velocity.
Vr = Observed Velocity.
d = Depth or Sounding.
d' = Depth minus immersion.

The account of the experiments from which this formula was deduced, and also the method of deduction, will be found in Francis' book on "Hydraulic Experiments at Lowell."

In order to show graphically the different results obtained by using observed velocity, and same as corrected by the Francis formula, all of the sets have been platted to scale showing mean area line, observed and reduced velocity lines and respective discharge lines. (Figs 80. 81.)

DETERMINATION OF SLOPE.

Two (2) gauges were set at points respectively 1,000 feet above and 1,000 feet below the discharge section. These gauges were carefully graduated to hundredths of a foot and were read three times a day. The readings were taken with an ordinary fishhook used as a hook gauge and were estimated to one one-thousandth of a foot, and reduced to simultaneous times The idea of using a fishhook originated with Mr. Morey, who was on the work with us, and worked very well. We found that with it when the water was still we were justified in reading the

gauge to thousandths; whereas ordinarily, even in quiet weather, reading to hundredths is about all you can do. The zeros of the gauges were connected by Wye levels, the mean of several runs being taken. From gauge 13.0 to gauge 15.3 the conditions were very favorable, the water being perfectly smooth and quiet. From gauge 13.0 to gauge 10.8 the water was always disturbed more or less by wind, and it is not believed that those observations are of much value. One good determination was obtained, however, at gauge 9.97, there being at the time a slight skimming of ice and hence no disturbance from wind.

The object of computing a discharge curve is to find out what the probable discharge will be for water elevations higher than those measured, it being assumed that if the discharge seems to follow some regular law within the limits of the observations, it will probably follow the same law for higher gauges.

The values of C in the formula $V=C\sqrt{rs}$ have been computed, using both observed and reduced values of v. The values of N (coefficient of roughness) in the Kutter formula

$$C=\frac{\dfrac{1.811}{N}+41.65+\dfrac{0.00281}{s}}{1+\dfrac{N}{\sqrt{r}}\left(41.65+\dfrac{0.00281}{s}\right)}$$

have been computed for each set, using both Cm and Cr.

The Kutter formula is designed to give a value for C in the formula $V=C\sqrt{rs}$ involving the hydraulic radius r, the slope, and a coefficient N, depending upon the nature of the wetted perimeter.

A full description of the data upon which this formula is founded, together with the method of deducing it, will be found in Ganguillet and Kutter's book on the "Flow of Water in Rivers and Other Channels."

The selection of the proper value of N for a given case is, according to Kutter, a matter of judgment. He suggests mean values to be used for six (6) different categories which, he says, however, are not to be rigidly adhered to, as follows:

I. Channels lined with carefully planed boards or smooth cement .... N=0.010
II. Channels lined with common boards............ N=0.012
III. Channels lined with ashlar or neatly-jointed brick-work .... N=0.013
IV. Channels in rubble masonry.................... N=0.017
V. Channels in earth brooks and rivers............. N=0.025
VI. Streams with detritus or aquatic plants.......... N=0.030

For values of N, computed from the Kutter formula for Gary measurements, see last two columns of tabulated statement. It will be observed in that statement of results that the velocity is

TABLE XXIX.

SHOWING VALUES OF A, V_m, V_r, Q_m and Q_r WITH VALUES OF C_m IN FORMULA $V_m = C_m\sqrt{rs}$ and C_r IN FORMULA $V_r = C_r\sqrt{rs}$.

Set No.	Water Elev.	Area A	Wetted Perimeter P	Hydr'lc Radius r.	Slope in feet per foot s.	Velocities* Reduced† V_m	Observed V_r	Discharges‡ Using V_m AV_m	Using V_r AV_r	Values of C_r, C_m in formula $C_r = \frac{V_r}{\sqrt{rs}}$	$C_m = \frac{V_m}{\sqrt{rs}}$	Values of α in formula below¶ Using C_r	Using C_m
1	15.60	2148.10	274.86	782	0.0000796	1.99	2.04	4265.66	4374.57	81.93	79.92	0.0287	0.0290
2	15.60	2148.10	274.86	782	0.0000796	1.91	1.94	4093.93	4170.77	77.91	76.71	0.0289	0.0293
3	15.14	2025.19	266.70	759	0.0000762	1.90	1.96	3846.26	3975.98	81.50	79.00	0.0273	0.0283
4	14.44	1846.81	252.80	731	0.0000714	1.75	1.82	3239.49	3354.45	79.69	76.75	0.0280	0.0290
5	14.31	1814.72	252.10	720	0.0000707	1.64	1.71	2981.21	3112.04	75.80	72.70	0.0295	0.0307
6	14.16	1777.64	251.20	708	0.0000697	1.61	1.68	2856.25	2986.88	75.68	72.52	0.0292	0.0307
7	14.10	1761.84	250.90	702	0.0000694	1.65	1.72	2898.71	3024.87	77.93	74.76	0.0282	0.0296
8	13.20	1539.19	247.25	622	0.0000646	1.46	1.52	2239.80	2346.40	76.00	72.85	0.0282	0.0296
9	13.04	1500.22	246.60	6.08	0.0000638	1.42	1.48	2128.30	2220.93	75.13	72.08	0.0284	0.0297
10	12.19	1285.37	233.80	5.50	0.0000604	1.32	1.39	1699.93	1783.96	76.37	72.53	0.0271	0.0288
11	12.12	1269.38	233.60	5.43	0.0000601	1.27	1.32	1606.51	1680.07	73.09	70.17	0.0285	0.0297
12	11.61	1147.93	227.80	5.07	0.0000585	0.98	1.03	1130.33	1181.84	59.81	56.98	0.0345	0.0363
13	11.52	1129.40	229.80	4.91	0.0000582	1.09	1.15	1227.81	1298.82	68.05	64.50	0.0299	0.0316
14	10.87	981.30	219.00	4.48	0.0000567	0.90	0.94	880.92	920.85	59.12	56.60	0.0337	0.0352
15	10.80	966.37	218.80	4.42	0.0000566	0.91	0.94	875.87	912.35	59.49	57.60	0.0335	0.0346
												0.4436	0.4621
										Mean Values of α.		0.0296	0.0308

* Velocities given in feet per second

† Velocities reduced by Francis formula

$$V_m = V_r\left(1.012 - 0.116\sqrt{\frac{d'}{d}}\right)$$

in which d is the total depth of the stream and d' the depth of water below the bottom of rod.

‡ Discharges given in cubic feet per second.

¶ Values of α deduced by the following formulas,

$$\text{using } C_r = \frac{\frac{1811}{\alpha} + 41.65 + \frac{0.00281}{s}}{1 + \frac{\alpha}{\sqrt{r}}\left(41.65 + \frac{0.00281}{s}\right)} \qquad \text{and using } C_m = \frac{\frac{1811}{\alpha} + 41.65 + \frac{0.00281}{s}}{1 + \frac{\alpha}{\sqrt{r}}\left(41.65 + \frac{0.00281}{s}\right)}$$

rather suddenly decreased in sets Nos. 12, 14 and 15, and the corresponding values of N are increased. This is undoubtedly due to wind, as it is noted in the field-book that there was a strong wind nearly straight upstream while those sets were being taken. No correction has been applied for wind in any of the sets.

The following is a list of the observations taken under the most favorable conditions:

	Gauge.	Slope in feet per foot.
	15.31	.0000775
Group 1	15.23	.0000755
	15.14	.0000775
Mean gauge	$= 15.23 = g$	Mean slope $= .0000768 = s$
	13.26	.0000655
Group 2	13.15	.0000630
	13.00	.0000645
Mean gauge	$= 13.14 = g'$	Mean slope $= .0000643 = s'$
	$9.97 = g''$	$.0000554 = s''$

Dividing the observations into groups as shown above and computing the mean gauge and mean slope for each group we obtain the three points

$$g = 15.23 \qquad s = .0000768$$
$$g' = 13.14 \qquad s' = .0000643$$
$$g'' = 9.97 \qquad s'' = .0000554$$

In order to get a mean line or curve to represent slope at all stages of the water, the three points above are assumed to be on a parabola whose equation is determined as follows:

The equation of the parabola referred to a tangent a the vertex is

$$y^2 = 2\,p\,x$$

Let m and n = the co-ordinates of the vertex of the parabola.

For the three points whose co-ordinates are y, y' and y'' and x, x' and x'' make $y = (g+m)$ $y' = (g'+m)$ and $y'' = (g''+m)$ and $x = (s-n)$, $x' = (s'-n)$ and $x'' = (s''-n)$

and let $C = 2p$.

Substituting these values in the general equation we get

(1) $(g+m)^2 = C\,(s-n)$

(2) $(g'+m)^2 = C\,(s'-n)$

(3) $(g''+m)^2 = C\,(s''-n)$

Expanding same we have

(4) $g^2+2gm+m^2 = C\,(s-n)$

(5) $g'^2+2g'm+m^2 = C\,(s'-n)$

(6) $g''^2+2g''m+m^2 = C\,(s''-n)$

Subtract (5) from (4)

(7) $g^2-g'^2+2m\,(g-g') = C\,(s-s')$

and subtracting (6) from (5) we get

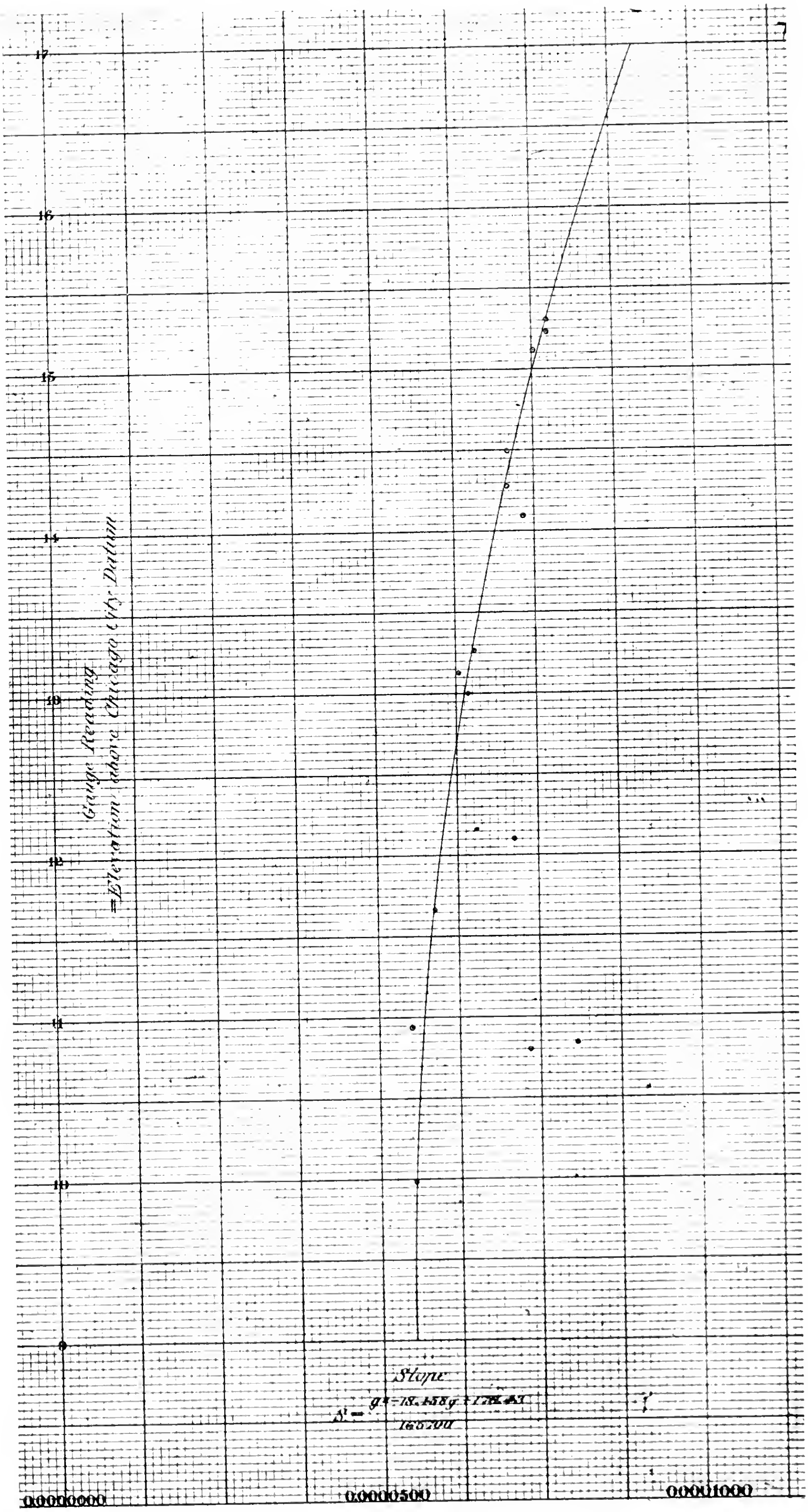
(8) $g'^2-g''^2+2m\,(g'-g'') = C\,(s'-s'')$

or

$$(9) \quad \frac{g'^2-g''^2+2m\,(g'-g'')}{s'-s''} = C = \frac{g^2-g'^2+2m\,(g-g')}{s-s'}$$

and substituting above values of g, g', and g'' and s, s' and s'', we have

$$\frac{231.95-172.66+4.18m}{.0000125} = \frac{172.66-99.40+6.34m}{.000089}$$



Slope in feet per foot.

FIG. 82. VARIATION OF SLOPE WITH GAUGE.

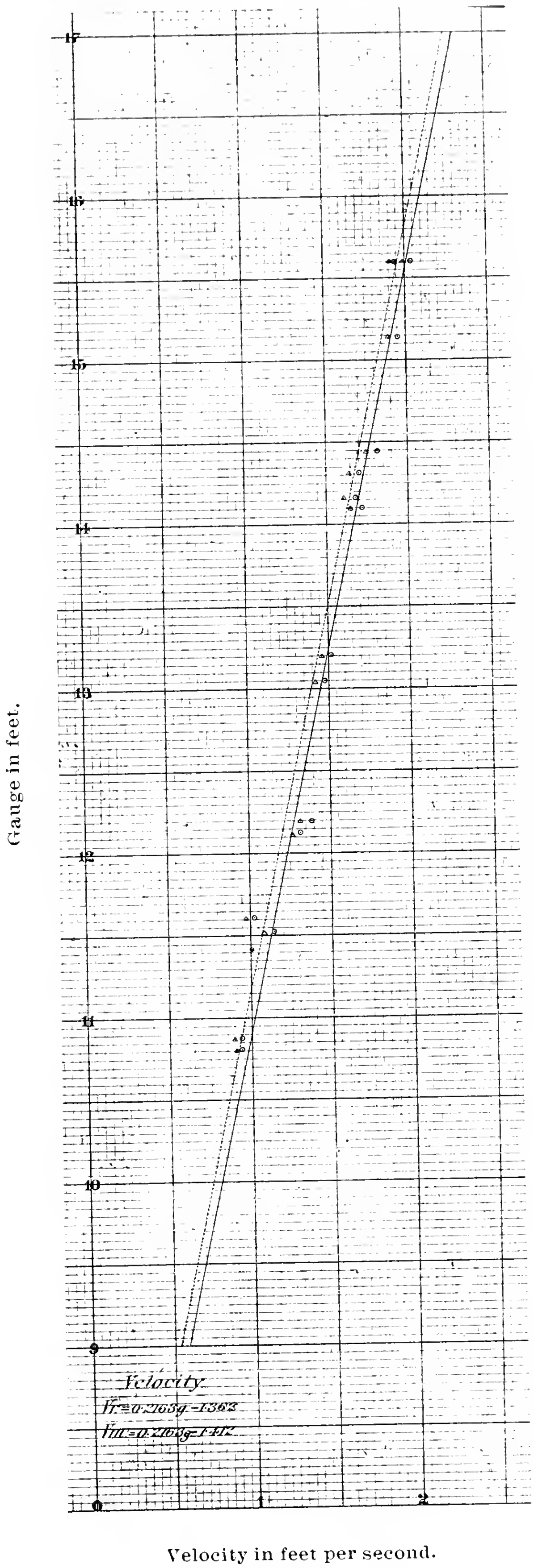


FIG. 83. VARIATION OF VELOCITY WITH GAUGE.

NOTE: Dotted line and △ pertain to reduced velocity, Vm in Table XXIX.
Full line and ○ pertain to observed velocity, Vr in Table XXIX.

$$\text{or } m = -9.23$$

Substituting above values of m in (9) we get

$$C = \frac{59.29 - 38.578}{.0000125} = 1{,}657{,}000$$

Substituting above values of m and C in (1) we get

$$n = 0.00005507$$

Substituting values of m, n and C in equation (4) we get

$$g^2 - 18.458g + 85.178 = 1{,}675{,}000s - 91.2545$$

$$\text{or } s = \frac{g^2 - 18.458g + 176.43}{1{,}657{,}000}$$

which is the equation of the curve. (See Fig. 82.) Substituting different values of g in above equation, we get

Gauge	Slope in feet per foot.
9	.0000551
10	.0000554
11	.0000570
12	.0000597
13	.0000637
14	.0000688
15	.0000752
16	.0000827

The values of s used in the computations for the various sets were deduced from above equation.

OBSERVED AND REDUCED VELOCITIES. (Fig. 83.)

Using the gauge readings as ordinates and the *observed* velocities as abscissae, all the observations were platted. It was noticed that a straight line drawn by eye through the points would give about the average velocity for any gauge height. Accordingly two groups of points were selected, and the mean gauge and mean velocity for each group being determined, a straight line was passed through the two points thus found.

GROUP 1.

	Gauge.	Velocity (observed) in feet per sec.
	15.60	2.04
	15.60	1.94
	15.14	1.96
Mean gauge	15.45 $= g$. Mean Vel.	1.98 $= v$.

GROUP 2.

	Gauge.	Velocity (observed) in feet per sec.
	12.19	1.39
	12.12	1.32
	11.61	1.03
	11.52	1.15
	10.87	0.94
	10.80	0.94
Mean gauge	11.52 $= g'$ Mean Vel.	1.13 $= v'$.

The equation of a straight line referred to rectangular axes is

$$x = my + C.$$

Substituting v for x and g for y we get for the two points whose co-ordinates are g and v and g' and v' respectively.

$$(1) \quad v = mg + C.$$

$$(2) \quad v' = mg' + C.$$

Subtract (2) from (1) we get $v - v' = m\,(g - g')$,

$$\text{or } m = \frac{v - v'}{g - g'} = 0.2163 \; (= tg\ 12^\circ\ 12').$$

Substituting value of m in (1) we get $C = -1.36$, and equation (1) becomes $V = .2163g - 1.362$, which is the equation of the line.

Computing V for different values of g, we have

Gauge.	Velocity in ft. per sec.
10	0.80
11	1.02
12	1.23
13	1.45
14	1.66
15	1.88
16	2.09

Using *reduced* velocities, and passing a straight line through the mean points of the same groups used before, we get for the equation of the line

$$V = .2163\,g - 1.412.$$

The different values of V for assumed values of g in latter equation are

Gauge.	Velocity in ft. per sec.
10	0.75
11	0.97
12	1.18
13	1.40
14	1.61
15	1.83
16	2.04

AREA CURVE. (Fig. 84.)

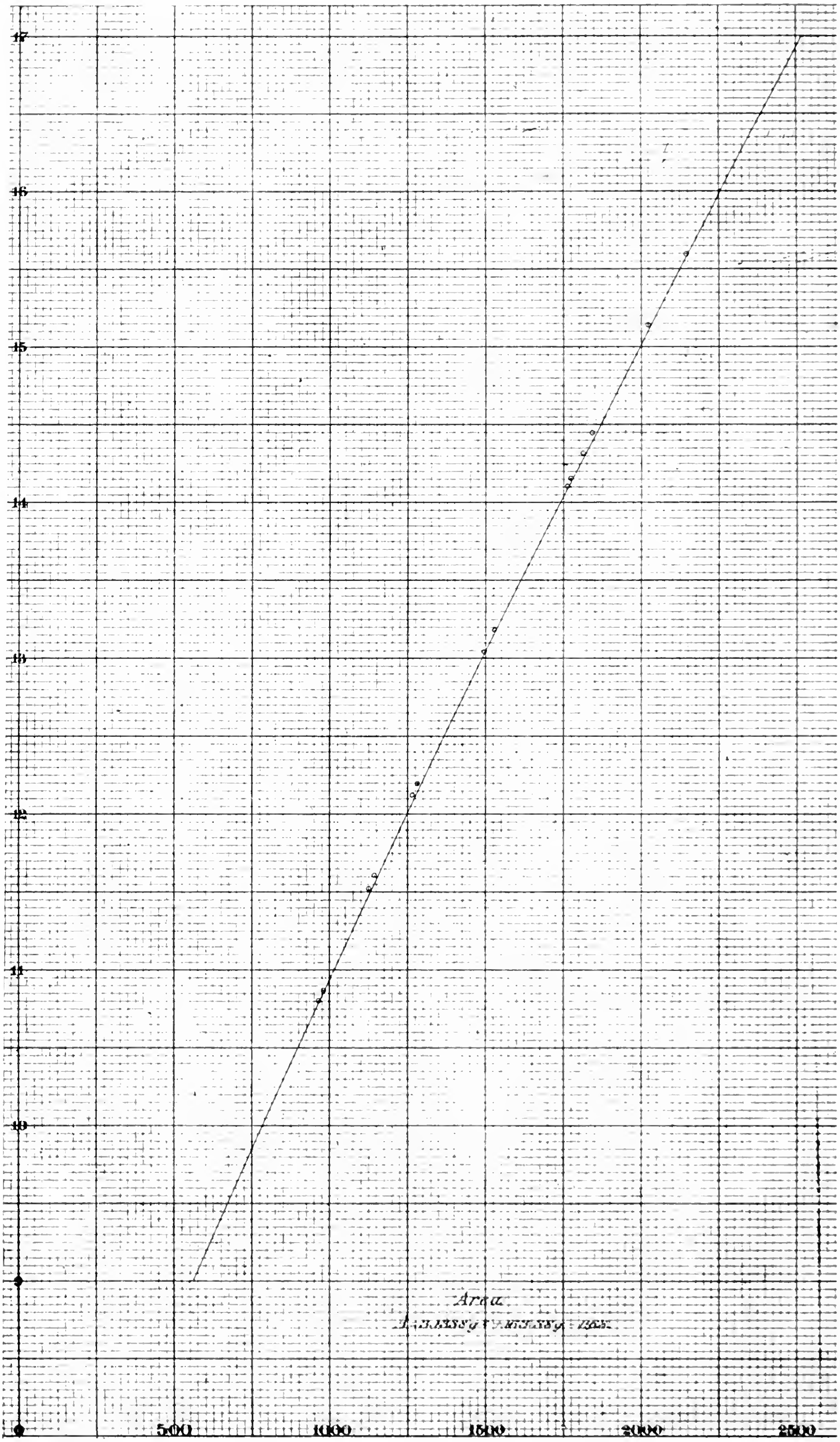
The area for each set was computed from the mean section (Fig. 85), which was obtained in the following manner:

Let d, d' and d'', respectively, equal the elevation on the upper, middle and lower ranges at any distance x from the base, then the mean

$$\text{Elev.} = \frac{d + 2d' + d''}{4}$$

The various computed areas being platted, it was noticed that they seemed to lie upon a slightly curving line. Taking the three points whose coördinates are $g = 15.6$ and $a = 2148$, and $g' = 13.2$, $a = 1539$ and $g'' = 10.8$, $a'' = 966$, as being upon a parabolic curve, and working out the equation in the same manner as was done for the slope curve, we get for the equation of the curve passing through them,

Gauge in feet.



Area in square feet.

FIG. 84. VARIATION OF AREA WITH GAUGE.

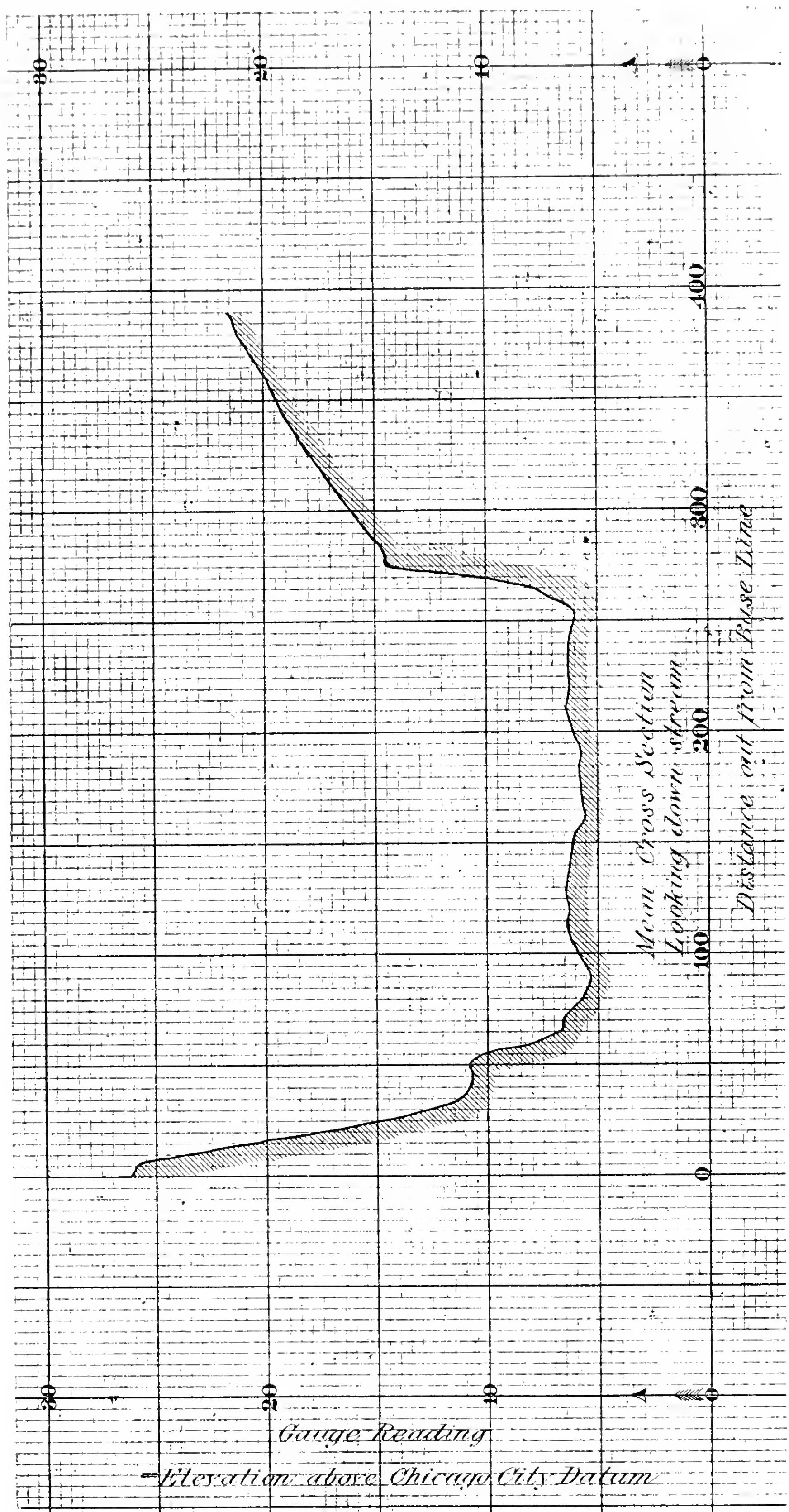


Fig. 85. Cross-Section of Channel at Location of Measurements.

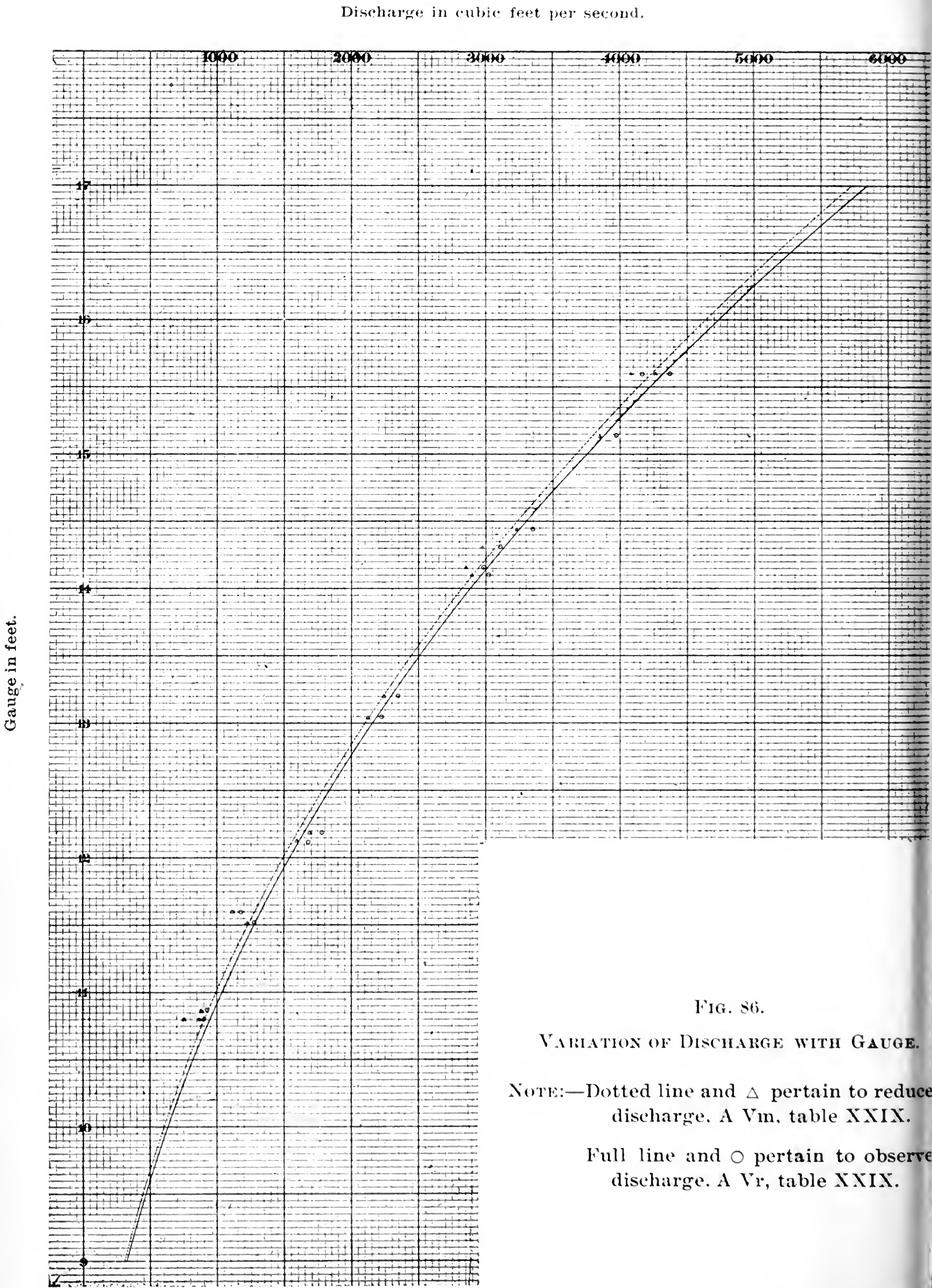


FIG. 86.

VARIATION OF DISCHARGE WITH GAUGE.

NOTE:—Dotted line and △ pertain to reduced discharge. A Vm, table XXIX.

Full line and ○ pertain to observed discharge. A Vr, table XXIX.

$$a = 3.1338\,g^2 + 163.38\,g = 1163.$$

Evaluating which for various gauge heights gives:

Gauge.	Area.	Gauge.	Area.	Gauge.	Area.
10	786	13	1492	16	2254
11	1015	14	1740		
12	1250	15	1994		

DISCHARGE CURVES. (Fig. 86.)

The discharge for each particular set was computed in the following manner: The mean section and water surface being platted, ordinates were drawn often enough so that the straight lines connecting their extremities would fairly well represent the bottom. The velocities were then platted at the points were floats were run and velocities interpolated from these, at the centre of each small area. The summation of areas by velocities gives the total discharge.

Since the discharge = area x velocity we obtain the equation of the discharge curve, using observed velocity by multiplying the area equation by the observed velocity equation, or

$$Qr. = \underset{A.}{(3.1338g + 163.38g - 1163)} \times \underset{Vr.}{(.2163g - 1.362)} = 0.67784g^3 + 31.0703g^2 - 474.08g + 1584$$

And in like manner:

$$Qm = \underset{A.}{(3.1338g^2 + 163.38g - 1163)} \times \underset{Vm.}{(.2163g - 1.412)} = .67784g^3 + 30.9136g^2 - 481.25g + 1641.$$

The substitution of different values of g in the above gives the following values of Qr. and Qm.:

Gauge.	Qr. (Cu. ft. per Sec.)	Qm. (Cu. ft. per Sec.)
10	628	599
11	1031	991
12	1541	1490
13	2161	2099
14	2896	2824
15	3751	3667
16	4729	4632

DISCUSSION.

Mr. John Lundie—How is the exact measurement determined?

Mr. W. T. Keating—By rod-floats—for instance, in the first set the gauge was 15.6, and as the bottom of the river is about 6, there was pretty nearly 10 feet of water in the river at that time, we ran rod-floats immersed 9 feet, every 20 feet, the distance out from shore being known by the tags on the wire cable we had stretched across the river about 30 feet above the upper range. Floats were started on the line of the cable, so as to give them a chance to get straightened up before they crossed the upper range. They were timed by a stop-watch for 100 feet distance; the reciprocal of the time in seconds, multiplied by 100, would give the velocity in feet per second for each float.

Mr. Lundie—I understand the method, but didn't I understand Mr. Keating to say that this was checked by weir measurements?

Mr. Keating—No, sir; I was speaking about some experiments made by Francis, in Lowell; I was explaining the Francis formula; we had no weir at all at the time.

Mr. Henry Goldmark—I would like to ask whether the slope, some distance up stream, was about the same as it was on the distance covered by the measurements?

Mr. Keating—The slope was measured by setting the gauges 1,000 feet up stream, and 1,000 feet down, and that covered the distance, 2,000 feet.

Mr. Goldmark—And the width of the stream was fairly constant?

Mr. Keating—Yes, fairly constant.

Mr. F. P. Kellogg—I would like to know how many observations were called a set, or the number of observations or floats that passed the different ranges.

Mr. Keating—I said we ran floats about every twenty feet out in the channel. Close up to the bank we might run them oftener, but on the average about 20 feet all the way across the channel, so that 200 feet would have about ten floats; that we call a set.

Mr. J. C. Bley—Taking the middle of the stream, for instance, was the float always kept the same depth from the bottom, or was the bottom of the float changed in depth so as to observe whether there was any difference in velocity?

Mr. Keating—The bottom of the river is about level all the way across; it may vary for a foot or so, as an extreme variation. We ran the same immersion all the way across the 200 feet—that is, we ran the float, immersed at the same depth, all the way across. At the beginning we had 10 feet of water and we had a float 9 feet long, and then at the end, where we had only about 5 feet of water, we had a float about 4 feet long.

Mr. Bley—Was there any great difference in the inclination of the float?

Mr. Keating—Well, we did not observe as to that. We always

tried to have only about 2 or 3 inches of the float sticking up, so that the wind would not affect it, and from that 2 or 3 inches we could not tell what the inclination was.

Mr. Kellogg—The data that Mr. Keating has collected are quite valuable, particularly on the value of the coefficient N, and I should like to see the results published.

Mr. Lundie—I am very much interested in this matter. How was the equation for slope determined?

Mr. Keating—We had observations three times a day, the water going down all the while; going down 5 feet in the length of time we were there—about three or four days. At the highest gauge reading, about 15.6, we got three observations that agreed pretty well with each other, the water having gone down two or three tenths between the first and the third. Taking the mean of these three observations—that is, computing the sine of the slope for the first one, and for the second and for the third, and then adding them all together and dividing by three, we get for the mean gauge reading a mean slope. Then, taking three more observations similarly when the water had fallen half way, or when the gauge read about 13 feet, we took three other observations that agreed very well with each other, and determined the mean gauge and the mean slope from them, thus determining another point. We had one more observation, which was the only good one we had for a low gauge reading. We took that as it was, without averaging it with anything. That gave three points, and from these three points was derived a curve to represent the variations of slope with gauge height. In order to get an equation, or something from which we can figure the value of slope at any gauge reading, we assume these three points to be on a parabola and work out its equation, and that was the equation I have read. Substituting any value of G, you get the value of the slope at that time.

Mr. Lundie—Now, then, doesn't the discharge depend very considerably on the correctness of the Francis formula?

Mr. Keating—I have it both ways. I have got it figured using the velocity straight as observed, and the same when reduced by the Francis formula; you can see what difference it makes; it is some three or four per cent, on the average, or five. Of course, the amount that that formula will reduce the velocity depends on the immersion. When the immersion is only half the depth the reduction is greater than when it is close to being all the depth. When the rod reaches within say half a foot from the bottom, the reduction by the formula will amount to very little.

Mr. Lundie—I would like to hear the Chair on this paper.

Mr. T. T. Johnston—If there is no further discussion, the Chair will take pleasure in adding a few remarks, prepared somewhat hastily, after seeing Mr. Keating's paper.

The important element in Mr. Keating's paper is the values determined for the coefficients in the Chezy and the Kutter formulae,

particularly in the latter, because there is so radical a scarcity of experimental data of this kind pertaining to channels of the size of Desplaines river diversion, and of cross-section sufficiently regular to render the results of value. The width of the channel was about 200 feet, and the depth during the time of measurements varied from 4 feet to 10 feet. The only experiments in channels at all similar, of which I know, are a few made some years ago in India. They are about thirty in number, and are published in the Hering and Trautwine translations of Ganguillet and Kutter. The Kutter coefficients determined by Mr. Keating are higher than those of the translation referred to, which fact is undoubtedly due to the scattered weeds in the bed of the river diversion channel.

The uncertain element in calculating the flow of water through any channel is the selection of a value, in any formula that may be used, for that coefficient which measures the frictional resistance to flow. For instance, suppose it be required to calculate the flow through the south branch of the Chicago river when the fall of water surface is one foot per mile. The first thought that would occur to the engineer would turn on the resistance to flow caused by the many bridge piers and projecting bridge approaches. After a little thought he would doubtless give the problem up as being difficult to solve. If, however, the bridges were not there, he would probably take Kutter's formula and assign a value to "N" varying from 0.025 to 0.030, and feel that the results of the calculations would be quite a close approximation. It happens that the sanitary district has made a number of measurements of flow in the river, with all its bridges in existence, and these have determined a value for "N" varying from about 0.040 to about 0.053, according to the point of the river in which the slope was measured, the slope having been measured continuously over a distance of about four miles. The wide difference of flow due to the various resistances is apparent.

Now, since Mr. Keating's measurements were made in a quite regular channel, and the sides and bottom thereof were quite different from those of previous experimental data in channels of the same size, the coefficients thereby determined are particularly valuable.

The subject in hand quite naturally has a bearing on the calculations by which the dimensions of the Chicago main drainage channel were determined. Unlike other large canals, the main purpose has been to create a flow of water in large volume. The only experimental data giving anything like a direct precedent were the few made in India and already referred to, and these were far from satisfactory. It may be stated briefly that the whole field of experimental data was carefully examined and studied, with a view to obtaining as much suggestion as practicable. It was found that, for channels of the size and nature of the Chicago canal, none of of the so-called hydraulic formulae could be accepted as expressing the variation of slope, hydraulic radius and velocity, one with another. Furthermore, the canal was to be thirty miles long, and

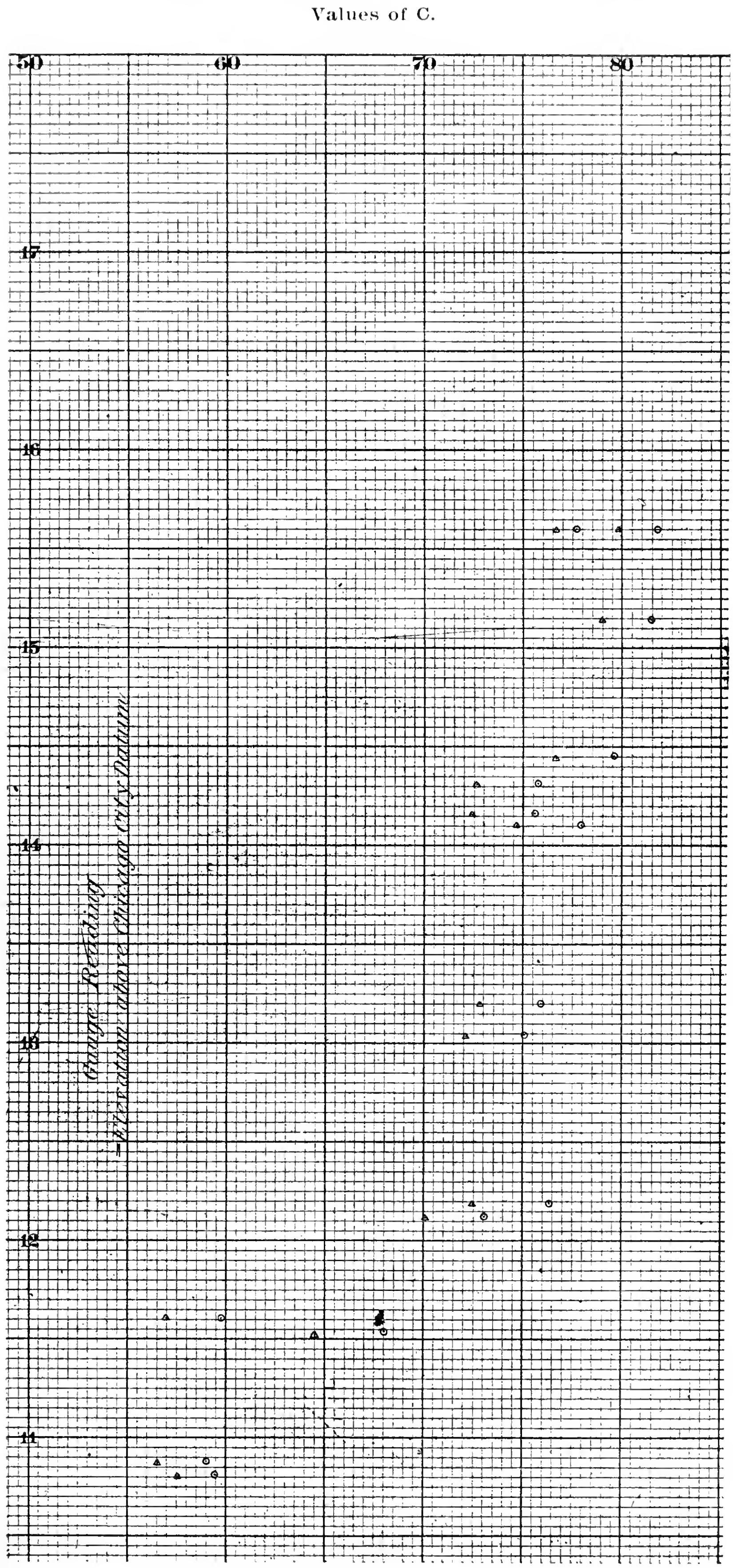


FIG. 87. VARIATION OF VALUE OF C IN $V = C\sqrt{rs}$, WITH GAUGE.

NOTE:—△ pertains to value of C corresponding to Vm, Table XXIX.
○ pertains to value of C corresponding to Vr, Table XXIX.

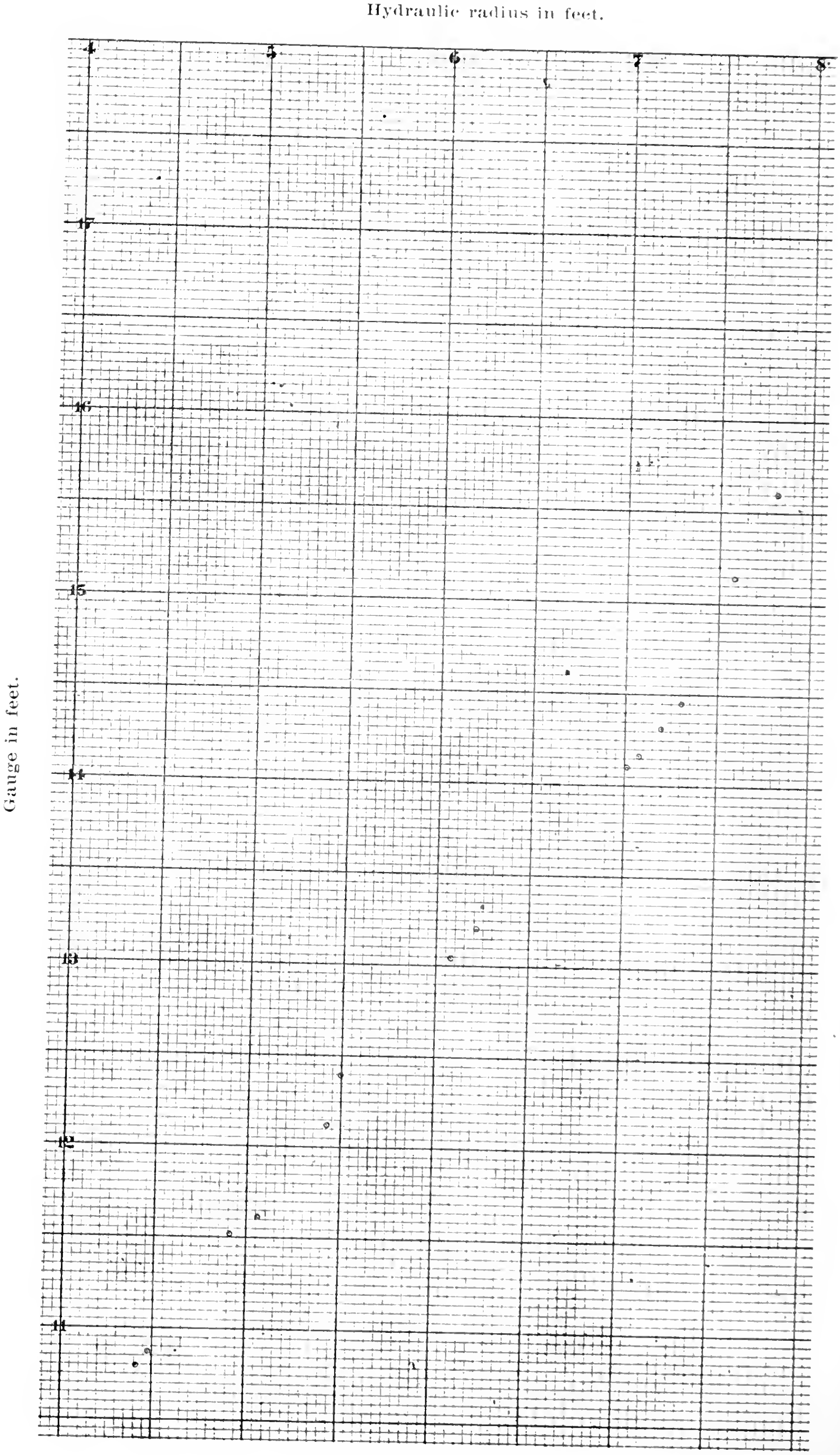


FIG. 88. VARIATION OF HYDRAULIC RADIUS (r) WITH GAUGE.

was to have bridge piers at some parts, and was to be more or less covered with ice at times, and at other times was to have its flow obstructed by boats tied at its shores. As to the effect of these things there was at first absolutely no data, and it was not until the question of dimension had been practically settled that the indications of the Chicago river experiments were available. The Sanitary District has had a number of chief engineers, and in accordance with their several views, coupled with one attendant circumstance or another, there have been various determinations of dimension and slope, into the nature of which it is not necessary to go at this time. The long story may be made short by saying that the dimensions, as they now exist, taking cognizance of the uncertainties above noted, were determined by the use of the following formula:

$$V = 22.39 \; r \, s^{1/2}$$

In which V = mean velocity in feet per second.
r = hydraulic radius
s = slope.

The constant "22.39" appears extended to an unnecessary decimal, but it happens to be the number corresponding to the logarithm 1.35.

This formula has seemed to be as satisfactory as any within the range of the variables involved in the problem, but cannot be taken for use in any other particular case. In its application to the canal it gives very nearly the same results as Kutter's formula would if the value of "N" therein be made 0.029. It is better than Kutter's formula because of its simplicity, which has much facilitated many calculations which would otherwise have been very tedious.

Experimental data, for the most part, pertains to short selected lengths of channels, whereas the practical case, more often than otherwise, involves a long channel, the flow in which is more or less resisted by various causes. Assigning a value to the influence of these miscellaneous resistances has been and still is a matter of difficulty. The capacity of the older Chicago water tunnels, of the Fullerton Avenue conduit and the Illinois and Michigan canal, were all much overestimated, simply because too small an estimate was made of what may be called the accidental resistances to flow.

TOPICAL DISCUSSIONS.

I

HYDRAULIC CEMENT.

(Continued from page 83.)

CEMENTS IN MORTARS AND CONCRETES.

By W. L. Marshall, Major Corps of Engineers, U. S. A.

In using hydraulic cements in combination with sand as mortar, and with sand, gravel and broken stone as concrete, there has been much said and written as to the proper proportions of water.

In all tests of neat Portland cements it has been clearly demonstrated that briquettes made with approximately the amount of water required for crystallization, i. e., with from 18 to 23 per cent of the weight of the cement (of water), give the strongest results at all ages. When sand mixtures are submitted to favorable conditions, well known and recognized by all engineers, similar results are attained in mortars mixed stiff. But in going from plain sand and cement mixtures to concretes, composed of mixtures of mortar, with broken stone, broken brick, crushed pottery, gravel and other materials coarser than sand, there is a great diversity of opinion and practice, in each case founded upon results of experience. There seems no common ground, nor point of tangency and assimilation of these diverse opinions, yet, surely, there is an explanation of this disparity of views and opinions among practical engineers, and it is possibly a matter that may be described and formulated when in any special case the character of the work, the quality of the labor, size and qualities of the components of the aggregate mass, possible care in mixing and placing the concrete, and limits of cost, are known.

On one side we have distinguished engineers who say that in concretes the aggregates shall be so dry that only ramming shall compact them; on the other hand are engineers, equally eminent in the profession and usually right in the special case, who say that the mass shall quake like unto liver when deposited; others still prescribe not only quaking on deposit, but also ramming in layers of definite thickness.

It is objected that in dry mixtures there is a lack of plasticity or mobility under pressure or ramming that will not admit of a dense concrete (and the experiments of Bammer are quoted); and that the arching of the aggregate will prevent effective ramming. In wet mixtures, that a quaking mixture of broken stone and grout is in hardening a weak and pervious material, like chalk, tufa, or pumice stone; that the matrix absorbs water and will fall to pieces under frost and water treatment and exposure. And still further, that no mixture that quakes on deposit can possibly be rammed, and that no specification that requires a quaking on deposit, and that also requires ramming, can possibly be carried

out; that it is an impracticable specification, and can only result in a mass of fragments connected by grout. This latter proposition admits of no discussion, it is self-evident.

In this discussion it has been shown that grout after a year or more acquires a tensile strength nearly approaching mortar made with much less water, but is of less gravimetric density. There are no experiments that show that concrete is improved in strength, when properly constituted, by water in excess of what is necessary to give a plastic matrix while at the same time supplying all chemical demands of the cement.

Portland cement requires all the water necessary for its crystallization, which is from 18 to 23 per cent of its weight, depending upon its chemical constitution and degree of vitrification. When made into mortar or concrete additional water must be added to allow each particle of the coarser material to be smeared over or coated with this cement.

Mortar of one part cement to say three parts dry sand will take at least 45 per cent of the weight of the cement of water to give a stiff mixture. When dry broken stone or pebbles are added, the proportion of water may reach 60 to 75 per cent of the weight of the cement, even in "dry mixtures" depending upon the relative volumes of cement and coarser materials. When such an aggregate is of the best quality, i. e., when the materials vary in fineness from cement, through sand of varying sized granules, torpedo sand, fine and coarse fragments, or pebbles and broken stone, in ascertained proper proportions to secure density, and properly mixed in batches by intermittent machinery, the apparent voids will be nearly all filled when the concrete is deposited, and compacting by ramming will give the best possible results when there shows moisture on the surface, but no slopping or quaking; the extreme proper limit of water supply is indicated by apparent moisture or incipient quaking.

In using broken stone only, screened to size as usually sold in the Chicago market, with all dust and all small particles removed, dry mixtures cannot well be compacted by ramming unless there is a sufficiently large excess of mortar over voids to act as a dry lubricant between stones, on account of the tendency to wedging or arching of the stones, and the want of fluidity or mobility in the matrix. In such cases, instead of a large excess of mortar, if the mortar be so watered that the stones by their own weight will bury themselves in the mortar, and the mortar flow into the voids under pressure, a better result will be obtained by mixing the concrete wet and simply treading it into place, than by mixing dry and failing to compact by ramming.

Where there is an improper aggregate, poor supervision, and careless contractors and workmen, better results can be had by poor work with wet mixtures than under precisely the same conditions with mixtures that are too dry to be mobile. A little too wet is better than a little too dry, under such conditions. It is believed also that in small masses and shapes, where ramming may

not be readily done or great pressure applied, that quite a wet mixture is more advisable, and will give better results than an improperly rammed and compacted dryer mixture. This is a compromise for cost, on account of, or because of, the difficulty of practically attaining theoretical perfection. In such cases the proportion of cement should be increased if equal strength with stiff, well compacted mixtures is desired.

These are the bases and origin of the specifications for quaking mixtures. The question seems to be one of expediency and practicability in each case, and that in deciding upon the question of the character of the mixture as regards water, among other things the following matters should be considered:

1. What is the aggregate, is it varied in size of particles from finest to coarsest, angular or rounded, or both; or is it composed of cement and sand and angular fragments only, the latter of nearly uniform size?

2. How is the mixture to be effected, by hand or by machinery? (In hand-made concretes water is more important as a vehicle.)

3. For what purpose is the concrete to be applied, in massive construction or in small molded forms in place?

4. What is the character of the labor, careful and painstaking; or is it directed only for a great output?

5. What is the allowable cost of the concrete (effective ramming is expensive)?

I am decidedly of the opinion that an excess of water is injurious as much in concretes as in mortar, and that where a strong dense concrete is desired, the best result can be had, and is had, by in the first place carefully providing a proper variegated in size aggregate, mixing by machinery with water sufficient to give a stiff coherent mass when rammed: all that it will take and allow ramming; the mixing to be made by an intermittent mixer, in batches of one cubic yard or more, mixed for as long a time as practicable before incipient set, or without pulverization of stones at angles. And that the ramming into the molds shall be carefully done by corrugated or tooth-faced rammers to resemble puddling of clay, to keep the surfaces always rough and to transfer the compacting action of rammers to the bottom of the layer as far as practicable and to give better bond with subsequent layers. In contracted places where ramming cannot be well done, or is too costly, it is allowable to increase the proportions of mortar or cement and to add water even, in some cases, until the heavy aggregate by its weight shall force the matrix into all voids and angles, but the result will be both weaker and lighter than if it were possible to use dryer mixtures of the same constitution.

It is unquestionable that the best mortar and the best concrete will be made from any sufficient mixture properly compacted when the mortar has plasticity sufficient to be readily used and as near the water required for crystallization as may be. In any case of plastic mortars or concretes the water is necessarily in excess of chemical demands.

When more water is used than necessary plasticity demands, it can be justified by questions of practicability and expediency in the case at hand, that indicate weaker concrete or more cement, because in the special case the best results cannot be economically attained with dryer mixtures, or because strength may be sacrificed in the case and other more important gains effected.

The practice in dealers in concrete stone to screen out the smaller particles of broken stone should not be encouraged. All particles of tangible size, not dust, should be retained, and the stone consist of all attainable sizes—from one-eighth of an inch up to the maximum size allowable.

Experiments made at this office also show that an admixture of not much exceeding 10 per cent of the weight of the cement, of limestone dust, does not reduce the strength of Portland cement mortar, but seems rather to increase tensile strength, although every adulteration of the kind reduces the tensile strength of neat cement mixtures. It seems to be a question, therefore, whether crushed limestone should be screened at all for concrete. The same series of tests (carried on, however, for too short a period) seem to indicate that impure limestone sands procured by crushing and sifting to the American Society standard, give mortars of greater tensile strength than the standard crushed quartz sands. Such mortars will not stand abrasion so well as quartz mortars, and probably will be unequal to them in crushing strength.

In practically mixing mortar by hand the following method has been adopted and for some time used on the Hennepin Canal (Illinois & Mississippi Canal):

1. The cement and sand are mixed dry.
2. The mixture is cast upon a screen, No. 3 to No. 5.
3. The mixture is wetted and turned.
4. It is cast through a screen, No. 3.

All nodules, principally composed of pure Portland cement, are mashed by shovels and returned to the wet mixing box.

5. The wet mixture is cast upwards by shovels upon two or three platforms, then on to cars and transported to the lock walls.

This mixing is so thorough that sand briquettes made therefrom give results as large as our laboratory experiments.

We find it very important to cast the wetted mixture upon screens, because of the tendency to "ball up" into small nodules. These nodules seem almost free from sand, and if put in the facing make it appear when cut like a conglomerate stone. If the mixture were very wet, doubtless these nodules would flow and disappear, but in that case on ramming or even by pressure of superincumbent masses water would exude between the planks of the forming, carrying off the fine cement and leaving the facing so poor in cement and porous that it would be worthless in work subjected to blows and abrasion.

This has been tried and rejected, and it is found necessary that the facing of works subject to wear shall be of such consistency that no flowing of the cement shall take place in ramming.

PLASTERING.

In Mr. Johnston's discussion in dealing with "Plastering," the work on the sea wall, south of Lincoln Park, is given as an instance of "notable failure," and in comparison, by inference, the plastering of the dam constructed by the Sanitary Board at the head of the Ogden ditch as a notable success.

It is not intended to justify the sea wall south of Lincoln Park, nor to criticise the plastering of the dam named. The Lincoln Park work was inaugurated by the Commissioners of Lincoln Park after receiving the advice of several prominent members of the Western Society of Engineers. The advice received was correct, for the best and most durable construction, and the modifications of it by the Lincoln Park Board, contrary to the opinions of all their engineer advisers, to meet the conditions imposed by money cost, have produced some of the results predicted beforehand and now apparent to the successors of that board. The only failure there has been a failure of the wall to tumble into the sea and to be in useless ruins as predicted by all engineer advisers of the board. The foundation on which the wall is placed is entirely insufficient. It consists in a double row of piles, of unknown penetration, 9′ 6″ apart, and three layers of 3″ oak plank capping them. The sea wall is of detached blocks of concrete 10′ high and with the top 11′ 6″ above city datum, 4′ long (measured along the wall), and of about 6′ base, weighing each about 11 tons, set end to end on this platform. The sea has ready access under the foundation, and at every storm waves strike violent blows, not only upon the face of the wall, but also on the bottom of the foundation platform, to which they have free access through open piling. Proper rip-rapping has also been neglected under the seaward front of the wall. These heavy and almost continuous blows cause very noticeable vibrations and tremors in the wall, which are continually increased in extent, due the excavation by receding waves in front of the pile foundation.

At the time the wall was built—1886-1888—the lake level was from 2 to 3 feet above Chicago city datum, and the Commissioners of Lincoln Park were unable to construct a proper water-tight rigid foundation at city datum because it would have tripled the cost of the improvement. They desired the wall, but had not the funds to pay for a properly constructed one, and compromised.

There are 900 11-ton blocks in that work. Over the joints, to make smooth continuous connection, the superintendent of the work had stonecutters cut somewhat into the irregular stones and plaster over the dividing joints. Of these 900 plastered joints, between detached stones on a yielding platform, subjected to furious blows and vibrations continued through from eight to ten years along a very exposed lake frontage, probably at a dozen places the plastering has fallen off; at many other places it is cracked and loosened. It is miraculous that it is not all gone, and that the entire wall is not in the sea. It is, simply, in an engineering view,

a case of the unexpected (to engineers) success of risky engineering by lay bodies invested with temporary authority controlling public works. No good reason can be seen why the entire work is not in ruins; but, on the contrary, for all purposes of a sea wall it is as good as new, but somewhat defaced by injury to plastering. The result, however, may be taken as justifying the Commissioners in constructing the wall. It cost over $100,000, and it is doubtful whether repairs to the wall itself or to its plastering in eight years has amounted to one-fourth of one per cent of its cost. But there has been much work on account of the washouts of backing through the open piles beneath the wall. The neglect of the foundation in not excluding waves and not providing sufficient riprap in front was the great error in this work. The plastering was an incident inseparable from the separate block construction which had been adopted prior to the writer's services as consulting engineer to the Lincoln Park Board. In further considering this wall, it must be understood that the Commissioners had in mind filling in, in front of this wall, out to the line of North Avenue and Ohio Street, improvements within ten or twelve years, and that they aimed only at such length of life for this wall.

The dam across the head of the Ogden ditch is on a solid foundation; is never subjected to furious blows and tremors; the plastering may stick; in this case the plastering was not a necessary incident to the construction, but was either an afterthought or deliberately adopted as proper. No reason can be given why it should not stick, beyond the fact that the cohesion along the surfaces of juncture between the natural and Portland cement concretes is not much in excess of one-third the strength of the weaker concrete. If its cohesion be sufficient to stand the stresses due frost and changes in temperature over the area of junction it will be successful; if not, it will fail. That plastering is under reasonably favorable conditions for exposed work. No more unfavorable conditions can be imagined than at the Lincoln Park sea wall. Ten years hence it will be known whether the plastering of Ogden ditch dam will have been as successful as that done at Lincoln Park. This is not the time to compare the two.

In work under my direction as a rule no plastering is allowed, and where there must be a junction of diverse mortars or concretes, where one element has already set, dovetails of sufficient size to take the stresses as tensile and compressive forces, relying not at all upon cohesion, are prescribed. A single, double or triple wash of pure cement to fill up pores and make a more watertight structure is allowable, but plastering in thicker layers than a wash after the setting of the main mass is a poor resort in all cases, except where the forces acting are not great at any time, and are uniform at all times.

EARLY STRENGTH OF CEMENT.

In cements many engineers and cement manufacturers are continually remarking that an early power of resistance may be developed at the risk of later failure. That has been dinned into us for years; but beyond tests for free lime, and change in volume and chemical tests for excessive magnesia and sulphate of lime, I have never been able to find any formulated rule under which a weak cement at short time (say 60-day) tests should be accepted and a much stronger cement be rejected as a sham and delusion. As instances of development of great strength in short time, the Alsen White Label and Star Stettin cements are examples, among other German cements, and the Atlas and Alpha, among other American cements of like quality; the latter have not, however, yet been subjected to long-time tests in heavy exposed works.

The Saylor's American Portland, among others of like quality, is an example of a comparatively weak cement under short tests, that increases much more in strength in time than the others named above, but probably does not at any time surpass them, but may be most advantageous to use in many situations. The four first named cements are treated with sulphate of lime; the Saylor's is not so treated. In my own works I specify the brands and makes, and as a rule will not receive bids from manufacturers that I do not know have furnished cements for successful exposed works existing in this climate for at least five years, that can at any time be seen and inspected.

If cements do not lose strength under long-time tests, but either gain or maintain themselves safely, then that cement among such proffered that gives the greatest strength in the shortest time at the least cost with sand mixtures is the one selected under the specifications for Hennepin Canal work. This rule requires previous acquaintance with the manufacture. An abnormal and unusual development of strength on short-time tests, or any other peculiarity in a known brand, would at once call for caution. Fortunately, under our proposals the rule has resulted in well-known, uniform and reliable cements being accepted, and the selections have been confirmed by longer tests.

In most cases where concretes are used, the stresses to which they must be subjected come upon them early, in thirty days or two months, and it little matters should a building fail, if that cement used in it one, two or five years after the failure from lack of strength, shall be found adamantine in strength.

Better let it be adamant in thirty days, and remain adamant. There are cements that attain near maximum strength in short time, and many of them that have under our eyes succeeded. In Chicago, for the last ten years, there has been a great development of concrete work. Much of it has failed, and more of it has been successful. It is not a difficult matter to pick out a list of half a dozen or more manufacturers of cement that have always furnished a reliable article, and have, therefore, increased their sales in Chicago;

and it is not a difficult matter by three-day, seven-day and twenty-eight-day tests with sand to select the apparently most economical cement among that half dozen or so, and by extending the tests the best among them for long-time exposures may be discovered for use in future in limiting the bidders admitted to the contest.

In making the briquettes for neat tests, it is almost immaterial how they are made. With equal proportions of water and almost irrespective of length of mixing, briquettes pressed in with trowel, thumb, or rammed, give not too widely varying results. With sand it is not so; thumbs vary in pressure. There is no comparison, with thumb pressure, between tests made by different persons. If mortars be mixed for one minute wet, they are not at all comparable with mortars mixed five minutes wet, nor either of them with mortars with ingredients persistently rubbed together for ten minutes after wetting. Nor are thumb-pressed briquettes comparable with hydraulic-pressed briquettes, or either of them with rammed briquettes.

Practically speaking, there is no such thing as "overmixing." In mixing mortars conditions are met with somewhat familiar to us in breaking in a new steel pen. Each grain of sharp sand has smooth facets and glazed; rub one of its facets over once with wet cement and it adheres only on part of its face; rub again and again, and it becomes coated. When all the surfaces of all the facets of all the grains of sand become coated with cement, then on properly pressing the grains together we will get a maximum strength for that cement with sand. In making concrete this process must be further extended, and now it is required to rub mortar again and again over each facet, and over many facets of each stone, until all the faces and facets of all the stones are covered with the cementing paste, to give the maximum strength. The rules of the American Society of Civil Engineers relating to sand tests especially need revising.

Let any member of this society experiment by mixing mortar. Follow, say, at first the rules of the American Society of Civil Engineers in making sand briquettes; mix thoroughly dry, then add all water, say 45 per cent of the weight of cement for a three to one mixture, at once; mix thoroughly, say half a minute, and then mold your briquettes, using thumb pressure. Then mix another batch with same ingredients and after adding water rub together the ingredients for, say, five or ten minutes, and mold as before. He will find an added strength of from 30 to 150 per cent in the latter briquettes. If this trituration or rubbing together of the sand and cement be continued up to a certain time, he will find his mortar continually becoming more plastic and workable, and the briquettes still stronger.

In concrete also by prolonged trituration or rubbing together of its constituents, as long as the time does not trench upon the setting of the mortar or the trituration result in rubbing and pulverizing the angles of the stone, the concrete will gain in strength.

It is possible to increase good concrete 200 per cent over usual practices by prolonged mixing or to materially reduce the quantity of cement used for the same strength. In such experiments in mixing mortars and concretes it is instructive to also examine the mixtures with a magnifying glass. One is astonished to find in mixtures not apparently very wet appearances of rills of not excessively muddy water flowing apparently over the surfaces of the granules. A comparatively short experience with such tests will result in such additions of water only as will allow a smearing over with cement paste of the surfaces, and convince one that water in excess is good so far only as it acts as a vehicle in imperfectly manipulated mixtures and imperfect aggregates in carrying some cement to points which otherwise no cement at all would reach.

The practice is a partial cure for bad manipulation and hasty work, and allows fair results at less cost than with less water, when the same imperfect manipulation and poor aggregates would be used. Prolonged mixing and perfect ramming are expensive operations that in many cases will not be justified.

The amount of water is a question not as to which is the best practice, regardless of cost, but what is the best practice under such and such conditions of labor, materials and limited cost. These conditions may be such as to demand grouting pure and simple, down through all grades of mortars and concretes to the most perfect artificial stones that take as near as practicable water for chemical necessities only. The question of wet and dry mixtures is plainly a question of expediency and cost, and of other special conditions, not a question of best attainable results at whatever expense.

It is noticeable that advocates of wet mixtures under all circumstances ridicule laboratory tests on mortars as worthless in concretes, but at the same time produce as their only argument, so far as relates to strength, results of laboratory tests on grout to maintain themselves, even though they are not even so maintained until a year or several years elapse after the construction has been brought into use. Many of us have seen poor results from grout as well as from other mixtures.

Similarly advocates of dry mixtures under all circumstances quote the French practice in "béton aggloméré," or "béton Coignet," and see no reason in wet mixtures, but oftentimes have to desert their principles or engage in malpractices.

In this matter no Procrustean rule is permissible, but the question, "What is the best proportion of water to be used in mortar and concretes of hydraulic cements?" may be well answered, "Any proportion demanded by the special conditions of the case."

Engineers may scalp each other over a wide field in arguing it more definitely, and some of us have been attacked in every part of this field. Some of us who use grout where Coignet mixtures are indicated, and quaking masses where dryer concrete is required, or who persist in the reverse practice out of place are justly scalped.

In my own practice there has just been made a recommendation to do many thousand cubic yards of thin grouting under pressure of pumps in the Washington aqueduct tunnel. There I am an advocate of fluidity in mortar. The Lincoln Park paved beach north of the inlet was laid in absolutely dry concrete mixture, and all the joints between paving stones were filled with dry constituents of mortar; afterwards the surface of the pavement was sprinkled to form a crust over this dry mixture, and other water needed was left to be taken up by the cement by capillary attraction from below or from the waves by percolation through this crust. In that case, directly to the contrary, I was an advocate for absolutely dry mixtures.

In one case our mortar will dry out and have sufficient strength still; in the other case it did not die for lack of water. These are the extremes, and the correct practice may possibly have been indicated in each case to secure necessary objects at least cost.

DISCUSSION.

Mr. F. P. Kellogg: Major Marshall has evidently given the matter a great deal of study and has had experience; being a government engineer, working for Uncle Sam, he generally has money to spend and draws his specifications, I believe, in such a way as to make first-class work. There is another side to look at. The contractor who bids so much a yard to put in concrete, of course wants to get off as easily as possible; he cannot do it when working for the government; the government gets good concrete out of him. That matter I believe Major Marshall has studied, because he was trying to make concrete for the Hennepin Canal for a certain figure; he examined the aggregate so as to obtain the cheapest mixture that he could, and having studied the problem in that way he has given us a great many good ideas. I would like to see the paper printed in our journal.

Mr. E. L. Ransome: There has been much said in that paper that is very interesting, but I notice that one point with regard to the question of water has not been touched upon. The advocates of what is generally known as dry mixture have but one experiment to fall back upon, made either with neat cement or with cement and sand. I see the Major says the same for the advocates of wet concrete, but that is not so. Mr. Bamber's experiment has been alluded to; I suppose it is known to most of you. Mr. Bamber made a box of two feet cube, he filled it with dry mixed concrete well compacted, then reversed the operation, added more water, re-mixed the concrete, put it back in the box, and then, instead of occupying the whole two feet in depth, it was concentrated to one foot ten inches; in other words, the concrete which was dry mixed occupied two feet cube, and after there had been added more water it did not take up as much space by two inches as it had before. Now that is an experiment that has never been answered by the advocates of dry mixtures. There have been no direct tests that I know of

published to show the relative strength of wet and dry mixtures made under otherwise similar circumstances. I made an experiment on one occasion in building the wall of a factory; I was using what would be termed a wet mixture. For the purpose of testing the matter I made a change one day and used a mixture comparatively dry, but not quite as dry as that which would ordinarily be known by that term. After a period of about three weeks I had blocks made by both methods cut out from the wall and the specific gravity of the two carefully taken. The result was a little in favor of the wet mixture, the specific gravity of the concrete made with a maximum of water being slightly greater than that made by the dry process. By testing them with hand, hammer and chisel, the difference was so marked that out of a dozen trials by a dozen different men the verdict was justified that the wet mixed concrete was the harder. It depends very much upon the aggregate; if you take an aggregate of a rounded character, such as a water worn gravel, then a dry mixed concrete is the better. But if you take an aggregate of crushed stone, or crushed stone and gravel mixed, or a gravel with angular faces, then nine times out of ten you will find the wet the best. The reason why a concrete quakes and does not stand ramming is not generally on account of its having too much water; it is due generally to too much cement. If you use merely enough water to get what is termed a dry mixture, it will be a little difficult to ram, but if you use pointed rammers with sharp edges and let them sink down below the surface, perhaps six or eight or ten inches, then they will begin to take effect. In work that you can compact by rolling instead of tamping, there is no difficulty in getting rid of the excess of water. I have a little experiment on certain work that has slabs about 20 feet square; I had that rammed as hard and as long as it was easy to ram the concrete, until it was fairly well rammed. This was a mixture that would approach a dry mixture and even then the surface was only wet in places, the water appearing only in hollow spots. I then put a roller on that work and in a few seconds I had the water running out of it and it continued running in that way for several minutes. I repeated that experiment, in fact it is no longer an experiment, it is used now regularly on a certain line of work and we find that we can dry out water by rolling where we cannot by any ordinary tamping. The reference made by the author to the French system is not applicable and is not appropriate to this question. The use of but little water in the Coignet system applies to hydraulic lime, not to Portland cement. Coignet found out that by using common hydraulic lime and very fine sand, the fine sand which they have there in large quantities, and very little water, he could get a very good stone which is now known as the Coignet beton. Of course the conditions are not at all similar to the conditions in making concrete where a larger aggregate is used. I should like, if there is any one who knows of any experiment that has been made to prove the strength of dry

concrete, to hear of it. The briquette test is certainly no criterion at all.

Mr. Kellogg: I do not know of any experiments that have been made with dry and wet concrete, but the experiment that the gentleman made with rolling is not surprising to me because I have had somewhat the same experience. The pressure that you get out of a small rammer is, of course, very different from that of a heavy roller; the use of the latter will make the water run from underneath the roller to some place that is not so wet and it will push the water to the surface as it becomes compacted. The explanation I believe of the fact that the contractor likes to use a wetter concrete is that it goes into place a little better. If he uses it too dry, it takes too much tamping to get it into shape, and the extra water that he puts in does not cost as much as the extra ramming required by the engineer. I am an advocate of wet concrete myself for the reason that it costs less to put in and it makes a better job besides. Dry concrete, as the gentleman says, is not the same thing as Coignet beton, which latter should always be a dry mixture. Major Marshall indicates that he is an advocate of wet concrete, and this is one reason why I think his paper a valuable one.

Mr. Henry Goldmark: I think there is a somewhat humble application of concrete made on a large scale in this city from which some points may be learned, and that is the use of concrete for sidewalks and cellar floors. In these I find a very great difference existing both in the grade of the work and in the prices paid. I had a chance during the last autumn to see the making of a concrete walk by the South Side park commissioners on Fifty-sixth street in Hyde Park. Their specifications are severe, their inspection extremely strict, and the results obtained there and on their older walks are most excellent, so that it is interesting to know that they do two things which are condemned by many engineers in the use of concrete for other purposes. They make a very dry concrete, using, it is true, small stones, not over three-fourths of an inch in size. The concrete is bedded on a well-drained base of cinders, which is compacted until it is not over two-thirds of its original thickness. They fill up their molds, which are five inches high, and ram the concrete down to four inches in thickness, making the mixture, as I said before, as dry as it can be used. The result is everything that can be desired and I think this is in line with experience in other lines of work, that is, that a dry mixture gives perfectly good results where it is used in thin layers and where it is possible to ram it very thoroughly. Certainly there have been Coignet betons thus made in this country of Portland cement and sand in layers not over four inches thick, but very thoroughly rammed. After twenty years' exposure their present condition is absolutely perfect, so that I think Major Marshall is entirely right in saying that the proper amount of water to be added is a question differing with the circumstances of each particular piece of work.

Mr. Ransome: I would like to say one word in regard to the

sidewalk construction. The reason they use their mixture so dry is because they cannot help themselves; it is absolutely necessary to finish the work in one day; if they put in the foundation of four inches of wet concrete, they cannot get a finished surface on within the twenty-four hours or certainly not during the day's work. It is not a question of strength, it is a question of time. I suppose any sidewalk man who has had any experience knows that if he could use a little more water he could get a better result. This point is, I think, very well conceded.

With regard to the use of Coignet beton in this country I would say that Coignet beton, properly speaking, is a mixture of lime and sand, not of cement and sand or of lime, cement and sand.

It was Coignet's discovery that by use of lime and sand in a comparatively dry state he could make an artificial stone, and I think it is conceded by all that if you use a mixture of cement and sand only the dry mixture is the best. I do not think there is any difference of opinion on that subject. A great many of these mixtures are what we term a rich, strong mixture. Now in the aggregates for sidewalks they seldom use less than one of cement to twelve of aggregate, but if you use one of cement to 15 or 20, as some of them do, and make a dry mixture, it will hardly hold together, whereas if you use more water and mix thoroughly, these weak concretes will not only hold together, but you will get astonishing results. For example, I made a mixture of one of Portland cement to twelve of aggregates, the aggregates being broken limestone as it came from the crusher, including the dust. It was turned in the mold 500 times, then compressed ordinarily, with ordinary ramming, no unusual ramming; that concrete stood a crushing strain of 94 tons in 14 days. On the contrary, an ordinary mixture of one cement to six aggregates, dry mixed, well rammed, would not stand half that strength in that time, it would not stand over 50 tons. There is a saving of over 50 per cent. of the cement and a better result. There is one thing I was a little surprised at in the paper, viz.: the Major's allusion to the use of sand in preference to the use of dust of stone. He makes one exception, however, in the case of limestone dust. It has been demonstrated by frequent experiments that not only limestone dust, but brick dust or sandstone dust, or almost any clean stone dust is preferable to ordinary sand. The experiments are conclusive on this subject, both here, and also in England, and it is a thing that can be demonstrated very easily and very readily by anybody. When I say stone dust I do not mean that you should take a No. 100 sieve and collect it from that, but should take it as it comes from the crusher. If you are crushing clean stone, all the dust that you remove from the crusher and replace with sand is to the detriment of the concrete. I think that that may be stated as a general fact.

Mr. T. T. Johnston: There is one brief word I would like to say with reference to the dam across the lead of the Ogden ditch, as Major Marshall has called it, really the spill-way of the Chicago

sanitary district. The body of the dam is made entirely of natural cement concrete, partly Louisville and partly Utica cement, and the face of it is plastered with a Portland cement coating, about two parts sand to one of cement. In the first place the coating was put on "deliberately as being deemed proper" and was contemplated when the dam was originally constructed. The dam was constructed in quite a hurry at the latter part of the fall of 1893, and too late to get the Portland cement coating on in the fall during which the dam was constructed, so that the dam was left exposed through all the winter months without any protection at all, the dam having been completed essentially in November. The following summer in June the work of putting the Portland cement plastering upon the dam was undertaken. The dam having been exposed through the winter, suffered somewhat from the action of the frost upon the concrete. That part of the cement concrete which had been laid a week or ten days before the cold weather started in, did not suffer materially from exposure during the winter, although the exposure was to quite severe extremes, there being quite a little soft weather and freezing weather alternately and during the spring of 1894, the water had flowed over the dam. That part of the dam which had been built after frost had set in and when the thermometer was below freezing point, suffered somewhat from the action of the frost, the outside concrete peeling off in some places a couple of inches deep and in some places as much as a foot deep. When the work of putting the plastering upon the dam was commenced, a wire broom was taken and the surface of the concrete brushed off as much as possible with the edges of a wire broom. In the parts where the frost had some action the concrete that was frosted fell off quite readily. After being brushed carefully, it was thoroughly washed by water pumped under a nozzle pressure, of perhaps 75 pounds, through an ordinary inch nozzle; the stream was directed against the wall at a distance of about 35 feet, so that it had a very good scouring. This being done, wooden forms were placed close to the surface of the dam, which were to be coated, both on the up and down stream surfaces, and the Portland cement plastering was rammed in behind and even where the coating was only three-fourths inches thick, tools were used to pack the plastering down behind the forms. That work was completed a year ago last June and this is the second winter that it has passed. I have not seen the dam recently, but on an examination last fall I went over its surface quite thoroughly and failed to find more than a square foot of concrete surface that sounded hollow. The adhesion between the Portland cement plastering and the natural cement concrete seemed to be quite satisfactory. The Major states that the adhesion between Portland cement plastering and the natural cement concrete should probably not be more than one-third the strength of the natural cement concrete. I am very much inclined to doubt the accuracy of that statement, as I have seen, and I presume all here may have seen, many cases of the adhesion of Portland cement

plastering to a natural cement concrete to such a degree that when the piece was broken, the line of fracture would not take place along the lines of contact between the Portland cement and the natural cement concrete. In the case of the spill-way, during the plastering, or rather shortly afterwards, I took a bricklayer's hammer and went over the surface at a number of points and undertook to separate the Portland cement plastering and the natural cement concrete and was unable to do it, the breaks taking place in the natural cement concrete. At that time, it would be safe to say that the strength of adhesion was greater than the strength of the natural cement concrete.

Mr. Geo. E. Thomas: I would like to say that Major Marshall is somewhat mistaken about the Lincoln Park sea-wall. Major Thomas Hanbury is the father of that sea-wall and I had charge of the work. For the first 600 feet the elevation is eight feet and the base of the stone is also eight feet wide. The stones are set on piles that had been driven some years previous for sea protection over there and the trouble that arose between engineers was this: some were in favor of having new piles driven and Major Hanbury with several other engineers determined that those piles were equal to the work required. The piles were not more than six inches apart in the clear, two rows of longitudinals eight feet apart on which there was a cap of 6x12 oak and then a three-inch plank. As the water at that time was about three feet higher than it is at present, there was a great deal of difficulty experienced in taking out the old material, but I never heard at that time that there was any difference of opinion with engineers as to the formation of the wall. Furthermore, those stones were made wholly of Portland cement concrete, that is, for the first 600 feet. After that I was called to Cincinnati to put up a bridge, and after I left and after Major Hanbury was removed, the form of the stone was somewhat changed; I think they cut the base down to four feet, or one-half its original width. That is the trouble with the sea-wall.

Mr. J. C. Bley: I am not interested very much in concretes directly, as it is somewhat out of my line, but I would like to mention an item I once picked up that rather corroborates some things I have heard to-night. I believe there was a Mr. Bamber spoken of this evening as performing a curious experiment. As I understand it, he filled a box full of material that was dry, then watered the stock and found that it would not fill the box. I heard of a rural engineer who performed about the same feat. He took a pail full of swill to a pig, the pig drank the contents of the pail, then crawled into the pail and did not fill the pail. I have been rather doubtful about the pig story, but since Mr. Bamber corroborates it, I am beginning to have a little faith in both experiments.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

STATUS, COST AND PROGRESS OF WORK ON THE CHICAGO MAIN DRAINAGE CANAL.

By U. W. Weston, Superintendent of Construction, and Isham Randolph, Chief Engineer.

A.—Excerpt from Annual Report for 1895 of U. W. Weston.
See Map, Fig. 49, for location.

Chicago, Jan. 23, 1896.

Isham Randolph, Esq., Chief Engineer:

Dear Sir—I herewith submit my report of the work of construction for the month of December, 1895, together with the usual tabulated statements showing the condition of the work at the close of the year. The weather has continued remarkably fine throughout the whole season, and the excellent record of the preceding year was largely exceeded. In fact, since the commencement of the work, all toward conditions seem to have united in the interest of the contractors, which has to a great extent contributed to their remarkable progress. Owing to variable and inclement weather incident to the winter months, these are not considered as a part of the working season, excepting in the excavation of the rock sections, most of which are practically completed. Out of a total of about forty million cubic yards of material, a little more than thirty-one million yards have been excavated, leaving a balance of about nine million cubic yards; and as the greater part of this material is glacial drift, the excavation of which is difficult and expensive at this season, but little progress may be expected therein until spring opens.

In the following report upon the status of the several sections, for the purpose of comparison, I give a summary of the quantities excavated annually—the last year being detailed monthly.

Section "O"—The conditions on this section are practically the same as heretofore reported, and but little progress can be made thereon until the arrangements recently made with the several railroad companies can be carried out, when the section will be accessible for dredging operations. The operations during December were confined to the vicinity of Rockwell street, and the material excavated was used in street filling to the amount of 3,400 cubic yards.

The following is a summary of the excavation done at the end of the year (exclusive of the Collateral Channel):

	Cubic Yards		
Total quantities			1,516,736
Amount excavated during 1894		518,821	
Amount excavated during 1895—			
January	......		
February	......		
March	......		
April	......		
May	2,800		
June	......		
July	2,700		
August	24,800		
September	10,200		
October	28,000		
November	39,100		
December	3,400		
Total for 1895		111,000	
Total to Jan. 1, 1896			629,821
Balance remaining			886,915

Section "N"—The same conditions exist upon this section as are noted in reference to the preceding section. Nothing was done on the section during the month of December and work will not probably be resumed until spring.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,113,843
Amount excavated during 1894		71,300	
Amount excavated during 1895—			
January	......		
February	......		
March	......		
April	......		
May	......		
June	5,100		
July	14,400		
August	......		
September	6,600		
October	22,300		
November	19,100		
December	......		
Total for 1895		68,500	
Total to Jan. 1, 1896			139,800
Balance remaining			974,043

Section "M"—This section was completed on the 4th of December, with the exception of the Santa Fe Railway crossing at Twenty-sixth street, for which no provision has yet been made.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			722,850
Amount excavated during 1894		343,800	
Amount excavated during 1895—			
January	22,800		
February	6,500		
March	32,400		
April	40,300		
May	62,200		
June	24,600		
July	31,300		
August	33,800		
September	27,100		
October	48,500		
November	37,800		
December	7,550		
Total for 1895		374,850	
Total to Jan. 1, 1896			718,650
Balance remaining			4,200

Section "L" was let to the same contractors as the preceding section, and the only work done thereon during December was finishing and trimming the slopes of the Main Channel and the surface ditches.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,101,881
Amount excavated during 1894		458,100	
Amount excavated during 1895—			
January	48,900		
February	15,800		
March	53,900		
April	64,500		
May	52,500		
June	103,400		
July	75,800		
August	86,800		
September	73,600		
October	50,391		
November	7,259		
December	3,000		
Total for 1895		635,850	
Total to Jan. 1, 1896			1,093,950
Balance remaining			7,931

Sections "K" and "I," both under the same contractors—Christie & Lowe—are practically finished, with the exception of the Belt

Line Railroad crossing at the east end of Section "K," for which no right has yet been acquired.

The following is a summary of the excavation done at the end of the year:

Section "K."

	Cubic Yards		
Total quantities			1,155,953
Amount excavated during 1894		414,600	
Amount excavated during 1895—			
January	21,400		
February	......		
March	40,000		
April	60,700		
May	73,700		
June	76,300		
July	66,400		
August	86,400		
September	95,700		
October	104,400		
November	58,000		
December	18,600		
Total for 1895		701,600	
Total to Jan. 1, 1896			1,116,200
Balance remaining			39,753

Section "I."

	Cubic Yards		
Total quantities			1,139,849
Amount excavated during 1894		680,400	
Amount excavated during 1895—			
January	44,900		
February	......		
March	28,100		
April	56,800		
May	64,800		
June	62,385		
July	70,715		
August	84,600		
September	32,300		
October	5,700		
November	......		
December	1,300		
Total for 1895		451,600	
Total to Jan. 1, 1896			1,132,000
Balance remaining			7,849

Section "H" has made very creditable progress during the year, notwithstanding accidents, which disabled a part of its plant for about five months. The Mason & Hoover conveyor was idle during

the month and will not probably resume operations before spring. The steel incline handled 26,983 cubic yards during the month of December, in 49 shifts—an average of 550 yards per shift.

The following summary shows the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,077,098
Amount excavated during 1894		141,444	
Amount excavated during 1895—			
January	4,874		
February	1,200		
March	6,990		
April	15,292		
May	9,128		
June	36,523		
July	67,740		
August	78,842		
September	73,887		
October	79,188		
November	58,706		
December	26,983		
Total for 1895		459,353	
Total to Jan. 1, 1896			600,797
Balance remaining			476,301

Section "G," belonging to the same contractors as the preceding section, has also made good progress within the past year and is in good condition. The usual plant was employed during December, and it is accredited with an estimate of 34,252 cubic yards.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,363,742
Amount excavated during 1894		527,906	
Amount excavated during 1895—			
January	16,094		
February	......		
March	9,900		
April	31,400		
May	48,499		
June	60,655		
July	53,321		
August	54,701		
September	44,163		
October	44,141		
November	40,259		
December	34,252		
Total for 1895		437,385	
Total to Jan. 1, 1896			965,291
Balance remaining			398,451

Section "F"—The new contractors, Weir, McKechney & Co., were considerably delayed in getting their machinery installed, owing to the failure or inability of the manufacturers to furnish same as promptly as was expected. This was followed by a series of mishaps to their truss conveyors that have greatly affected the output. Their plant is of the same character as that so successfully used on Sections "I" and "K" (designed and introduced by Christie & Lowe), and should be fully adequate for the requirements of the section. The last disaster that befell this section was on December 21st, when it was inundated during the high water of that period. Work was then suspended, and will not likely be resumed before spring.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,105,983
Amount excavated during 1893		246,543	
Amount excavated during 1894		257,750	
Amount excavated during 1895—			
January	......		
February	......		
March	......		
April	......		
May	10,500		
June	23,200		
July	22,500		
August	29,500		
September	45,800		
October	34,500		
November	30,100		
December	4,800		
Total for 1895		200,900	
Total to Jan. 1, 1896			705,193
Balance remaining			400,790

Section "E"—The contractors on this section, Angus & Gindele, have met with misfortune to about the same extent as those mentioned in the preceding section, having lost one large steam excavator by fire, shortly after its installation, and were unable to substitute other effective appliances in its stead before the unseasonable weather set in. They are now rearranging and increasing their plant to an extent that they estimate will more than double their former capacity and complete their work during the current year. During the month of December they operated two steam shovels, in connection with dump cars and locomotives, a total of 26½ shifts, excavating 15,100 cubic yards—an average of 570 yards per shift.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,894,463
Amount excavated during 1893		462,402	
Amount excavated during 1894		55,980	
Amount excavated during 1895—			
January	14,767		
February	4,814		
March	8,100		
April	35,800		
May	43,000		
June	62,200		
July	55,100		
August	73,600		
September	41,600		
October	47,500		
November	25,000		
December	15,100		
Total for 1895		426,781	
Total to Jan. 1, 1896			945,163
Balance remaining			949,300

Section "D" made fair progress during the year, and is so far advanced that its early completion may be expected. Twenty-eight thousand four hundred cubic yards of material were moved in December by three steam shovels in seventy shifts—an average of 406 yards per shift. Work was then suspended for the winter.

The following is a summary of the excavation done during the year:

	Cubic Yards		
Total quantities			2,014,168
Amount excavated during 1893		227,317	
Amount excavated during 1894		890,555	
Amount excavated during 1895—			
January	29,859		
February	26,669		
March	30,500		
April	58,800		
May	64,700		
June	64,500		
July	61,900		
August	60,200		
September	57,800		
October	37,300		
November	43,900		
December	28,400		
Total for 1895		564,528	
Total to Jan. 1, 1896			1,682,400
Balance remaining			331,768

Section "C" has also made a fair showing for the past year, but inasmuch as there still remains about as much material in the section as was excavated last year, greater effort will be required to clean up and finish the work within the present season.

During the month of December three steam shovels were engaged, 44 shifts excavating 19,300 cubic yards—an average of 439 yards per shift.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			1,887,381
Amount excavated during 1893		135,828	
Amount excavated during 1894		657,159	
Amount excavated during 1895—			
January	20,476		
February	......		
March	15,200		
April	65,200		
May	70,500		
June	93,000		
July	66,700		
August	49,700		
September	66,900		
October	54,300		
November	39,400		
December	19,300		
Total for 1895		560,676	
Total to Jan. 1, 1896			1,353,663
Balance remaining			533,718

Section "B"—For the first six months of the past year the work was restricted to the easterly half of this section. About May 1st the balance of the section was unwatered and dry excavation commenced thereon. The season's work has been highly satisfactory and the completion of the section may be assured during the present year. The output for December was 21,057 cubic yards, of which 1,000 yards was handled with manual labor and 20,000 with three steam shovels in 50 shifts—an average of about 400 yards per shift.

The following is a summary of the excavation done at the end of the year:

		Cubic Yards	
Total quantities			1,576,828
Amount excavated during 1894		600,477	
Amount excavated during 1895—			
January	28,707		
February	17,785		
March	17,720		
April	61,920		
May	80,134		
June	81,515		
July	56,854		
August	55,792		
September	62,423		
October	45,178		
November	41,252		
December	21,057		
Total for 1895		570,237	
Total to Jan. 1, 1896			1,170,714
Balance remaining			406,114

Section "A"—This is much the largest as well as the wettest section on our work. It was finally redeemed from confluence with the Desplaines River after much difficult labor in the building of a levee which was not completed until early last year, and the section could not be unwatered and gotten ready for dry excavation until about June 1st. Fortunately, however, the contractors have been able in the meantime to excavate over 850,000 cubic yards by hydraulic dredging, taking off all the overlying mucky material adapted to that process, while the river levee was being built. Thus there have been but about seven months of the past year during which dry excavation could be prosecuted, and while the results accomplished have not been satisfactory, there have been some mitigating circumstances for such a meager showing as is made. The spoil area is almost wholly confined to the northerly side of the Main Channel, and on the west half of the section it is not only limited, but is also quite marshy, and it was found very difficult to bring in and establish the necessary machinery and appliances upon such unstable material. To overcome these conditions has required more time than was anticipated, and has consumed the most of that part of the past working season in which they were engaged. To finish this section during the present season will require greater effort than is needed to complete any other unfinished section. The contractors seem to recognize this fact and are making preparations accordingly, with reasonable assurance of success.

The output for the month of December was 46,283 cubic yards, of which 41,200 yards were excavated by three steam shovels in 85 shifts—an average of 484 yards per shift; 3,800 yards by a slope excavator in 19 shifts—an average of 200 yards per shift, and the balance—1,283 yards—by teams and shovelers.

The following is a summary of the excavation done at the end of the year:

	Cubic Yards		
Total quantities			2,580,696
Amount excavated during 1893 with hydraulic dredge		90,859	
Amount excavated during 1894 with hydraulic dredge		768,463	
Amount excavated during 1895—			
January	13,404		
February	2,090		
March	4,287		
April	2,000		
May	......		
June	27,466		
July	21,700		
August	36,028		
September	22,880		
October	49,476		
November	41,611		
December	46,283		
Total for 1895		267,225	
Total to Jan. 1, 1896			1,126,547
Balance remaining			1,454,149

Section 1—Owing to a combination of circumstances this section has not made the progress that was expected during the past year. The principal cause for this seems to have been the introduction of a class of appliances that were not adapted to the character of the work in which it was intended to use them; this necessitated a change and the installation of a new plant, which consumed a good part of the working season. Upon a basis of value this is the farthest in arrears of any of the sections, but upon a quantity or yardage basis it is considerably in advance of the preceding section ("A"), and its completion during the present year is within range of proper effort.

All of the appliances provided for the work have been of superior quality, and the present available plant is very large and apparently adequate. The output for December was 18,900 cubic yards of glacial drift and 12,100 cubic yards of solid rock, a total of 31,000 cubic yards.

The following is a summary of the excavation done at the end of the year:

		Cubic Yards	
Total quantities			1,819,315
Amount excavated during 1893		99,332	
Amount excavated during 1894		323,834	
Amount excavated during 1895—			
January	22,200		
February	6,500		
March	53,900		
April	77,800		
May	57,000		
June	54,400		
July	67,600		
August	39,400		
September	41,500		
October	37,300		
November	56,100		
December	31,000		
Total for 1895		544,700	
Total to Jan. 1, 1896			967,866
Balance remaining			851,449

Sections 2 to 15, inclusive—These sections have all made such excellent progress during the past season, and the work thereon is either practically completed, or so far advanced, that it seems unnecessary to repeat here in detail that which is given in my former monthly reports; hence I give only a summary of the excavation done on each of the sections at the end of the year, and also the balance remaining to be done, by which it is apparent that all of this work will be easily finished within the present season.

Summary—Section 2.

		Cubic Yards	
Total quantities			1,202,613
Amount excavated during 1892		16,000	
Amount excavated during 1893		75,000	
Amount excavated during 1894		517,769	
Amount excavated during 1895—			
January	32,364		
February	16,447		
March	25,500		
April	53,020		
May	59,100		
June	66,900		
July	54,500		
August	60,000		
September	12,000		
October	6,600		
November	8,000		
December	12,000		
Total for 1895		406,431	
Total to Jan. 1, 1896			1,015,200
Balance remaining			187,413

Summary—Section 3.

	Cubic Yards		
Total quantities			1,181,982
Amount excavated during 1892		36,400	
Amount excavated during 1893		58,110	
Amount excavated during 1894		457,130	
Amount excavated during 1895—			
January	34,257		
February	36,013		
March	43,500		
April	61,100		
May	70,300		
June	67,600		
July	57,100		
August	58,000		
September	47,600		
October	42,600		
November	36,000		
December	21,200		
Total for 1895		575,270	
Total to Jan. 1, 1896			1,126,910
Balance remaining			55,072

Summary—Section 4.

	Cubic Yards		
Total quantities			1,340,675
Amount excavated during 1892		31,500	
Amount excavated during 1893		99,900	
Amount excavated during 1894		547,970	
Amount excavated during 1895—			
January	53,557		
February	24,773		
March	25,900		
April	75,600		
May	81,500		
June	90,700		
July	53,700		
August	66,000		
September	41,700		
October	19,000		
November	5,400		
December	13,200		
Total for 1895		551,030	
Total to Jan. 1, 1896			1,230,400
Balance remaining			110,275

Summary—Section 5.

		Cubic Yards	
Total quantities			1,329,854
Amount excavated during 1892		23,600	
Amount excavated during 1893		195,100	
Amount excavated during 1894		363,400	
Amount excavated during 1895—			
January	23,600		
February	17,300		
March	22,700		
April	50,000		
May	54,000		
June	70,400		
July	50,900		
August	52,000		
September	26,800		
October	36,800		
November	18,800		
December	14,300		
Total for 1895		437,600	
Total to Jan. 1, 1896			1,019,700
Balance remaining			310,154

Summary—Section 6.

		Cubic Yards	
Total quantities			1,234,274
Amount excavated during 1892		18,200	
Amount excavated during 1893		117,900	
Amount excavated during 1894		447,900	
Amount excavated during 1895—			
January	38,000		
February	21,600		
March	36,700		
April	43,800		
May	39,700		
June	47,800		
July	48,300		
August	53,200		
September	25,200		
October	30,200		
November	29,900		
December	28,800		
Total for 1895		443,200	
Total to Jan. 1, 1896			1,027,200
Balance remaining			207,074

Summary—Section 7.

	Cubic Yards		
Total quantities			1,072,744
Amount excavated during 1892		18,200	
Amount excavated during 1893		116,800	
Amount excavated during 1894		398,000	
Amount excavated during 1895—			
January	22,900		
February	19,100		
March	31,000		
April	42,700		
May	47,400		
June	48,200		
Jnly	43,200		
August	41,900		
September	42,400		
October	39,700		
November	24,100		
December	19,200		
Total for 1895		421,800	
Total to Jan. 1, 1896			954,800
Balance remaining			117,944

Summary—Section 8.

	Cubic Yards		
Total quantities			1,211,216
Amount excavated during 1892		8,970	
Amount excavated during 1893		75,130	
Amount excavated during 1894		579,500	
Amount excavated during 1895—			
January	41,400		
February	34,000		
March	44,200		
April	47,700		
May	33,600		
June	46,800		
July	44,900		
August	35,900		
September	28,100		
October	35,900		
November	31,000		
December	24,700		
Total for 1895		448,200	
Total to Jan. 1, 1896			1,111,800
Balance remaining			99,416

Summary—Section 9.

		Cubic Yards	
Total quantities			1,080,461
Amount excavated during 1892		10,400	
Amounted excavated during 1893		120,900	
Amount excavated during 1894		508,800	
Amount excavated during 1895—			
January	53,300		
February	43,300		
March	46,700		
April	51,600		
May	46,400		
June	51,000		
July	50,800		
August	45,800		
September	29,600		
October	21,291		
Total for 1895		439,791	
Total to Jan. 1, 1896			1,079,891
Balance remaining			570

Summary—Section 10.

		Cubic Yards	
Total quantities			1,173,633
Amount excavated during 1892		19,080	
Amount excavated during 1893		224,220	
Amount excavated during 1894		634,100	
Amount excavated during 1895—			
January	36,700		
February	27,300		
March	33,600		
April	43,200		
May	40,600		
June	35,400		
July	37,500		
August	33,000		
September	8,234		
Total for 1895		295,534	
Total to Jan. 1, 1896			1,172,934
Balance remaining			699

Summary—Section 11.

	Cubic Yards		
Total quantities			1,033,732
Amount excavated during 1892		37,700	
Amount excavated during 1893		269,700	
Amount excavated during 1894		371,932	
Amount excavated during 1895—			
January	20,300		
February	16,000		
March	18,800		
April	26,200		
May	33,300		
June	37,300		
July	41,000		
August	46,200		
September	41,900		
October	39,400		
November	27,050		
December	2,800		
Total for 1895		350,250	
Total to Jan. 1, 1896			1,029,582
Balance remaining			4,150

Summary—Section 12.

	Cubic Yards		
Total quantities			1,042,053
Amount excavated during 1892		37,653	
Amount excavated during 1893		285,547	
Amount excavated during 1894		326,700	
Amount excavated during 1895—			
January	42,700		
February	28,700		
March	42,661		
April	47,300		
May	43,400		
June	46,700		
July	31,900		
August	31,800		
September	31,770		
October	26,460		
November	7,080		
December	4,300		
Total for 1895		384,771	
Total to Jan. 1, 1896			1,034,671
Balance remaining			7,382

Summary—Section 13.

	Cubic Yards		
Total quantities			1,067,486
Amount excavated during 1892		63,522	
Amount excavated during 1893		346,100	
Amount excavated during 1894		496,900	
Amount excavated during 1895—			
January	17,400		
February	11,600		
March	22,700		
April	29,400		
May	27,800		
June	24,900		
July	6,900		
August	3,500		
September	5,500		
October	2,800		
November	2,500		
December	2,300		
Total for 1895		157,300	
Total to Jan. 1, 1896			1,063,822
Balance remaining			3,664

Summary—Section 14.

	Cubic Yards		
Total quantities			1,402,880
Amount excavated during 1892		35,800	
Amount excavated during 1893		126,571	
Amount excavated during 1894		477,129	
Amount excavated during 1895—			
January	35,100		
February	43,600		
March	62,000		
April	86,200		
May	81,500		
June	51,400		
July	71,000		
August	70,500		
September	67,300		
October	68,000		
November	37,900		
December	30,400		
Total for 1895		704,900	
Total to Jan. 1, 1896			1,344,400
Balance remaining			58,480

Summary—Section 15.

	Cubic Yards		
Total quantities			675,700
Amount excavated during 1894		39,200	
Amount excavated during 1895—			
January	6,700		
February	7,400		
March	11,600		
April	27,400		
May	36,300		
June	46,100		
July	44,200		
August	51,300		
September	52,300		
October	55,100		
November	34,400		
December	12,800		
Total for 1895		385,600	
Total to Jan. 1, 1896			424,800
Balance remaining			250,900

From the foregoing exhibit it will be observed that by the maintaining of former rates of progress the excavation on twenty-four of the twenty-nine sections will be finished during the current year. The five sections upon which greater effort must be put forth are Sections "A," "1," "E," "N" and "O," whose delinquency is in the respective order named. There is nothing to prevent a vigorous prosecution of the work on the three first named, and the contractors thereon seem prepared to do so, but on Sections "N" and "O" some time may be required to arrange for crossing the several railway lines; hence it is important that these matters be adjusted as early as possible.

Respectfully submitted,

(Signed) U. W. WESTON,

Supt. of Construction."

B.—Excerpt from Annual Report, 1895, of Isham Randolph, Chief Engineer.

See Map, Fig. 49, for location.

EXHIBIT B

Detailed Revised Estimate of January 1st, 1896.

Section.	DESIGNATION.	CUBIC YARDS—REGULAR CONTRACTS.			
		Main Channel.			*River Di*
		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.
O	Main Channel	1,504,736	....	....	....
	Collateral Channel	132,009	....	....	....
	Surface Ditches	12,000	....	....	....
	Western Avenue temporary bridge	....	....	....	....
	Totals for Section	1,648,745	....	....	....
N	Main Channel	1,105,443	....	....	....
	Surface Ditches	8,400	....	....	....
	Totals for Section	1,113,843	....	....	....
M	Main Channel	717,650	....	....	....
	Surface Ditches	5,200	....	....	....
	Totals for Section	722,850	....	....	....
L	Main Channel	1,094 081	....	....	....
	Surface Ditches	7,800	....	....	....
	Totals for Section,	1,101,881	....	....	....
K	Main Channel	1,147,753	....	....	....
	Surface Ditches	8,200	....	....	....
	Totals for Section	1,155,953	....	....	....
I	Main Channel	1,131,649	....	....	....
	Surface Ditches	8,200	....	....	....
	Totals for Section	1,139,849	....	....	....
H	Main Channel	1,073,645	....	....	....
	Surface Ditches	3,453	....	....	....
	Totals for Section	1,077,098	....	....	....
G	Main Channel	1,355,844	....	....	....
	Surface Ditches	7,676	....	....	....
	Extra Width	222	....	....	....
	Totals for Section	1,363,742	....	....	....
F	Ricker, Lee & Co	497,752	....	....	....
	Surface Ditches	2,300	....	....	....
	River Diversion, regular	....	....	....	65,308
	Borrow Pits for Levees	....	....	....	91,320
	Ditches	....	....	....	1,606
	Totals, Ricker, Lee & Co	500,052	....	....	158,234
	Weir, McKechney & Co	589,207	....	....	....
	Solid Rock	....	16,724	....	....
	Spillway Construction	....	....	....	....
	Excavation near Spillway—16,500 cu. yds. approximately	....	....	....	....
	Raising Santa Fe bridge	....	....	....	....
	Totals for Section	1,089,259	16,724	....	158,234

TABLE NO. 1.
For Summary of Values by Sections See Page 318.

		VALUES—REGULAR CONTRACTS.					VALUES—COLLATERAL CONTRACTS.
version.	Price.	*Main Channel.*			*River Diversion.*		
Solid Rock.		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	
....	$0.21	$ 315,994 56	....	....	....	....	....
....	.199	26,269 79	....	....	....	....	....
....	.21	2,520 00	....	....	....	....	....
....	....	....	....	....	....	....	$ 2,500 00
....	....	$ 344,784 35	....	....	....	....	$ 2,500 00
....	$0.23	$ 254,251 89	....	....	....	....	....
....	.23	1,932 00	....	....	....	....	....
....	....	$ 256,183 89	....	....	....	....	....
....	$0.217	$ 155,730 05	....	....	....	....	....
....	.217	1,128 40	....	....	....	....	....
....	....	$ 156,858 45	....	....	....	....	....
....	$0.197	$ 215,533 96	....	....	....	....	....
....	.197	1,536 60	....	....	....	....	....
....	....	$ 217,070 56	....	....	....	....	....
....	$0.25	$ 286,938 25	....	....	....	....	....
....	.25	2,050 00	....	....	....	....	....
....	....	$ 288,988 25	....	....	....	....	....
....	$0.25	$ 282,912 25	....	....	....	....	....
....	.25	2,050 00	....	....	....	....	....
....	....	$ 284,962 25	....	....	....	....	....
....	$0.29	$ 311,357 05	....	....	....	....	....
....	.29	1,001 37	....	....	....	....	....
....	....	$ 312,358 42	....	....	....	....	....
....	$0.28	$ 379,636 32	....	....	....	....	....
....	.28	2,149 28	....	....	....	....	....
....	.28	62 16	....	....	....	....	....
....	....	$ 381,847 76	....	....	....	....	....
....	$0.23¾	$ 118,216 10	....	....	....	....	....
....	.23¾	546 25	....	....	....	....	....
....	.23¾	....	....	....	$ 15,510 65	....	....
....	.23¾	....	....	....	21,688 50	....	....
....	.23¾	....	....	....	381 43	....	....
....	....	$ 118,762 35	....	....	$ 37,580 58	....	....
....	$0.29½	$ 173,816 07	....	....	....	....	....
....	.90	....	$ 15,051 60	....	....	....	....
....	....	....	....	....	....	....	$ 20,518 41
....	.7062	....	....	....	....	....	11,653 09
....	....	....	....	....	....	....	5,875 65
....	....	$ 292,578 42	$ 15,051 60	....	$ 37,580 58	....	$ 38,047 15

EXHIBIT B, TABLE

Section.	DESIGNATION.	CUBIC YARDS—REGULAR CONTRACTS. Main Channel. Glacial Drift.	Main Channel. Solid Rock.	Main Channel. Retaining Wall.	River Di[version] Glacial Drift.
	Streeter & Kenefick	467,640			
	River Diversion				68,768
	Borrow Pits for Levees				21,384
	River Diversion Ditches				5,566
	Totals for Streeter & Kenefick	467,640			95,718
E	Angus & Gindele	1,343,682			
	Surface Ditches	4,376			
	Solid Rock		78,765		
	Overhaul— 9,641 cu. yds				
	Summit Highway				
	Totals for Section	1,815,698	78,765		95,718
D		1,871,271			
	Surface Ditches	5,203			
			137,694		
	Raising Calumet Terminal bridge				
	Pile Trestle				
	Totals for Section	1,876,474	137,694		
C		1,853,324			
	Muck Berm	26,641			
	Surface Ditches	7,416			
					175,953
	Building Sand— 6253 cu. yds				
	Raising Illinois & Michigan Canal Bank				
	Totals for Section	1,887,381			175,953
B		1,576,828			
					212,486
	Raising Illinois & Michigan Canal Bank				
	Revetting Levee— 2000 cu. yds				
	Totals for Section	1,576,828			212,486
A		2,576,508			
			4,188		
					128,425
	Completing Levee— 87,261 cu. yds. Glacial Drift				
	Muck, Desplaines River— 122,342 cu. yds				
	Overhaul Levee Material— 50,893 cu. yds				
	Levee Trestle— 4,400 ft				
	Raising Illinois and Michigan Canal bank				
	Extra Depth, River Diversion— 21,225 cu. yds. Glacial Drift				
	Repairing Illinois and Michigan Canal Levees— Flood Damages				
	Removing Hard Material— Desplaines River				
	Removing Hydraulic Dredge— Trestle Expense				
	Revetting Muck Levee— 5,520 cu. yds				
	Totals for Section	2,576,508	4,188		128,425
1	Alfred Harley	109,540			
	Alfred Harley				5,876
	Heldmaier & Neu	11,926			
	Griffiths & McDermott	1,134,308			
			563,541		

NO. 1—*Continued.*

		VALUES—REGULAR CONTRACTS.					VALUES—COLLATERAL CONTRACTS.
version.	Price.	*Main Channel.*			*River Diversion.*		
Solid Rock.		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	
	$0.27½	$ 128,601 00					
	.27½				$ 18,911 20		
	.27½				5,880 60		
	.27½				1,530 65		
		$ 128,601 00			$ 26,322 45		
	$0.27	$ 362,794 15					
	.27	1,181 52					
	.70		$ 55,135 50				
	.26755						$ 2,579 45
							190 01
		$ 492,576 67	$ 55,135 50		$ 26,322 45		$ 2,769 46
	$0.26 7-16	$ 494,717 27					
	.26 7-16	1,375 54					
	.925		127,366 95				
							$ 1,880 54
							1,000 00
		$ 496,092 81	$ 127,366 95				$ 2,880 54
	$0.23½	$ 435,531 14					
	.23½	6,260 64					
	.23½	1,742 76					
	.23½				$ 41,318 96		
	.12½						$ 781 63
							579 08
		$ 443,534 54			$ 41,348 96		$ 1,360 71
	$0.27	$ 425,743 56					
	.27				$ 57,371 22		
							$ 1,680 12
	.20						400 00
		$ 425,743 56			$ 57,371 22		$ 2,080 12
	$0.30⅝	$ 789,055 58					
	.80		$ 3,350 40				
	.30⅝				$ 39,330 16		
	.36						$ 31,449 96
	.15						18,351 30
	.20						10,178 60
	1.954						8,597 35
							5,888 63
	.30⅝						6,500 16
							847 40
							285 60
							220 60
	.15						828 00
		$ 789,055 58	$ 3,350 40		$ 39,330 16		$ 83,147 60
	$0.27	$ 29,575 80					
	.27				$ 1,586 52		
	30⅝	3,652 34					
	.429	$ 486,618 13					
	.80		$ 450,832 80				

EXHIBIT B, TABLE

Section.	DESIGNATION.	CUBIC YARDS—REGULAR CONTRACTS.			
		Main Channel.			*River Di*
		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.
	....	....	....	54,395	....
	Totals for Griffiths & McDermott............	1,134,308	563,541	54,395	5,876
	Griffiths & McDermott, Slope Paving— 1,285 cu. yds..............	....	....	....	....
	River Diversion, Force Account— 158,617 cu. yds..............	....	....	....	....
	River Improvement, Force Account— 10,162 cu. yds..............	....	....	....	....
	Overhaul to Section A— 164,051 cu. yds..............	....	....	....	....
1	Willow Springs Road Levee, Force Account......	....	....	....	....
	Raising Spoil Bank Levee, Force Account........	....	....	....	....
	Clearing Land on River Improvement...........	....	....	....	....
	Willow Springs Road, Force Account...........	....	....	....	....
	Dyke at Columbia Park...........	....	....	....	....
	Raising Ill. & Mich. Canal Levee, Force Account.	....	....	....	....
	Removing Dam in River........	....	....	....	....
	Repairing Columbia Park buildings........	....	....	....	....
	Hay for Repairing Levee........	....	....	....	....
	Totals for Section........	1,255,774	563,541	54,395	5,876
	Slope Paving........	....	....	....	....
2	McArthur Bros........	29,675	....	....	....
		707,931	....	....	....
		....	465,007	....	....
		....	....	35,294	....
		....	....	....	29,516
	River Diversion, Force Account— 89,718 cu. yds. Glacial Drift........	....	....	....	....
	Totals for Section........	737,606	465,007	35,294	29,516
3	McArthur Bros........	73,310	....	....	....
	Gilman & Co........	340,775	....	....	....
		....	767,897	....	....
		....	....	13,307	....
	Totals for Section........	414,085	767,897	13,307	....
4	McArthur Bros........	48,593	....	....	....
		1,051,407	....	....	....
		....	240,675	....	....
		....	....	85,000	....
	River Diversion, Force Account— 106,803 cu. yds. Glacial Drift........	....	....	....	....
	17,857 cu. yds. Solid Rock........	....	....	....	....
	Totals for Section........	1,100,000	240,675	85,000	....
5	....	1,047,984	....	....	....
	....	....	281,870	....	....
	....	....	....	71,881	....
	Overhaul— 814,678 cu. yds........	....	....	....	....
	Quarrying Dimension Stone— 10,000 cu. yds........	....	....	....	....
	River Diversion, Force Account— 12,256 cu. yds. Glacial Drift........	....	....	....	....
	Removing Spoil Banks— 16,671 cu. yds. Glacial Drift........	....	....	....	....
	Rip-rap on Levee— 700 cu. yds........	....	....	....	....
	Totals for Section........	1,047,984	281,870	71,881	....
6	Vivian & Co........	24,100	....	....	....
	Mason, Hoge & Co........	651,132	....	....	....
	....	....	559,042	....	....
	....	....	....	28,500	....
	....	....	....	....	118,808

NO. 1—*Continued.*

version.	Price.	VALUES—REGULAR CONTRACTS.					VALUES—COLLATERAL CONTRACTS.
		Main Channel.			*River Diversion.*		
Solid Rock.		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	
	$2.90			$ 157,745 50			
		$ 486,618 13	$ 450,832 80	$ 157,745 50			
	$0.60	(771 00)					
	.865323						$ 137,254 90
	.42						4,268 04
	.20						32,810 20
							1,719 86
							1,044 05
							504 41
							778 22
							300 00
							241 57
							210 00
							30 00
							10 50
		$ 519,846 27	$ 450,832 80	$ 157,745 50	$ 1,586 52		$ 179,171 75
		(771 00)					
	$0.28	$ 8,309 00					
	.50	353,965 50					
	.80		$ 372,005 60				
	3.50			$123,529 00			
	.28				$ 8,264 48		
	.6131						$ 55,005 68
		$ 362,274 50	$ 372,005 60	$ 123,529 00	$ 8,264 48		$ 55,005 68
	$0.27	$ 19,793 70					
	.56	190,834 00					
	.76		$ 583,601 72				
	3.25			$ 43,247 75			
		$ 210,627 70	$ 583,601 72	$ 43,247 75			
	$0.27	$ 13,120 11					
	.49	515,189 43					
	.80		$ 192,540 00				
	3.50			$ 297,500 00			
							$ 79,910 23
		$ 528,309 54	$ 192,540 00	$ 297,500 00			$ 79,910 23
	$0.27	$ 282,955 68					
	.735		$ 207,174 45				
	3 25			$ 233,613 25			
	.04	32,587 12					
	1.00						$ 10,000 00
	.5097						6,246 54
	.27						4,501 17
	.70						490 00
		$ 315,542 80	$ 207,174 45	$ 233,613 25			$ 21,237 71
	$0.22	$ 5,302 00					
	.27	175,805 64					
	.735		$ 410,895 87				
	3.25			$ 92,625 00			
	.27				$ 32,078 16		

EXHIBIT B, TABLE

Section.	DESIGNATION.	CUBIC YARDS—REGULAR CONTRACTS. *Main Channel.* Glacial Drift.	Solid Rock.	Retaining Wall.	*River Di* Glacial Drift.
6	Embankment— 24,701 cu. yds.				
	Riprap on Levee— 5,469 cu. yds.				
	Hard Material on Levee— 11,000 cu. yds.				
	Raising Levee— 2,707 cu. yds.				
	Extra Appropriation for Raising Levee				
	Suppressing Fires in Levee				
	Totals for Section	675,232	559,042	28,500	118,808
7		172,500			
			900,274		
				6,000	
					97,917
	Quarrying Dimension Stone— 8,358 cu. yds.				
	Embankment— 3,517 cu. yds.				
	Raising Levee.— 1,466 cu yds.				
	Extra Appropriation for Raising Levee				
	Force Account, Raising Levee				
	Riprap— 4,277 cu. yds.				
	Earth Core for Levee				
	Hard Material on Levee— 4,000 cu. yds.				
	Suppressing Fires in Levee				
	Lumber for Piling Dimension Stone				
	Totals for Section	172,500	900,274	6,000	97,917
8		43,578			
	Approaches, Main Channel temporary bridge, Stephens Street	6,592			
	Main Channel, includ'g Retaining Wall scabbling		1,161,046		
					57,902
				2,875	
	Roadway and River Diversion bridge				
	Moving Cable Towers				
	Agnew & Co's. claims				
	Quarrying Dimension Stone— 1,400 cu. yds.				
	Trestle, Main Channel				
	Stephens Street Improvement				
	Moving Telegraph Line				
	Right of Way Fence				
	Totals for Section	50,170	1,161,046	2,875	57,902
9		76,692			
			1,003,769		
					40,763
	Agnew & Co's. claims				
	Main Channel Trestle				
	Totals for Section	76,692	1,003,769		40,763
10		31,743			
			1,141,890		
					30,313
	River Diversion Levee, Force Account				
	Roadway and River Diversion Bridge				
	Tracks at Quarry No. 5				
	Maintaining Western Stone Company's Tracks				
	Protection Levee at Quarry No. 5				

NO. 1—*Continued.*

...version.	Price.	VALUES—REGULAR CONTRACTS.					VALUES—COLLATERAL CONTRACTS.
		Main Channel.			*River Diversion.*		
Solid Rock.		Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	
	.65						$ 16,055 65
	.63						3,445 47
	.25						2,750 00
	.27						730 89
							1,200 00
							462 05
		$ 181,107 64	$ 410,895 87	$ 92,625 00	$ 32,078 16		$ 24,644 06
	$0.26	$ 44,850 00					
	.735		$ 661,701 39				
	3.25			$ 19,500 00			
43,102	.735					$ 31,679 97	
	.26				$ 25,458 42		
	1.00						$ 8,358 00
	.65						2,286 05
	.26						381 16
							2,800 00
							1,000 00
	.63						2,694 51
							2,000 00
	.25						1,000 00
							693 08
							400 00
43,102		$ 44,850 00	$ 661,701 39	$ 19,500 00	$ 25,458 42	$ 31,679 97	$ 21,612 80
	$0.26	$ 11,330 28					
	.26	1,713 92					
	.74¾		$ 867,881 89				
	.26				$ 15,054 52		
99,399	.74¾					$ 74,300 75	
	3.25			$ 9,343 75			
							$ 40,868 39
							2,992 15
							2,000 00
	1.00						1,400 00
							966 37
							500 00
							487 58
							222 02
99,399		$ 13,044 20	$ 867,881 89	$ 9,343 75	$ 15,054 52	$ 74,300 75	$ 49,436 51
	$0.26	$ 19,939 92					
	.769		$ 771,898 36				
	.26				$ 10,598 38		
16,873	.769					$ 12,975 34	
							$ 3,000 00
							1,012 30
16,873		$ 19,939 92	$ 771,898 36		$ 10,598 38	$ 12,975 34	$ 4,012 30
	$0.25	$ 7,935 75					
	.80		$ 913,512 00				
	.25				$ 7,578 25		
58,276	.80					$ 46,620 80	
							$ 24,063 17
							15,983 63
							3,120 89
							2,995 01
							1,400 58

EXHIBIT B, TABLE

Section.	DESIGNATION.	CUBIC YARDS—REGULAR CONTRACTS. *Main Channel.* Glacial Drift.	Solid Rock.	Retaining Wall.	*River Di* Glacial Drift.
10	Removing Western Stone Company's Tracks				
	Changing Western Stone Company's Tracks				
	Stairway to Main Channel				
	Moving Stairway and Platform				
	Totals for Section	31,743	1,141,890		30,313
11		44,021			
			989,711		
					5,834
	Core for Levee				
	Force Account River Diversion—				
	6,893 cu. yds. Glacial Drift				
	4,419 cu. yds. Solid Rock				
	Extra Work on Levee				
	Raising Levee				
	Totals for Section	44,021	989,711		5,834
12		29,318			
	Approaches to Bridge	12,470			
	Temporary Road	1,619			
	Side Pockets	632			
			978,182		
	Side Pockets		19,832		
				9,270	
					11,739
	Draining Goose Lake—				
	7,475 cu. yds. Solid Rock				
	Core for Levee				
	Main Channel Trestle				
	Romeo Roadway				
	Santa Fe Crossing at Romeo				
	Repairing Trestle				
	Totals for Section	44,039	998,014	9,270	11,739
13		33,036			
	Side Pockets	773			
			1,008,475		
	Side Pockets		25,202		
				10,838	
	Totals for Section	33,809	1,033,677	10,838	
14		167,280			
		212,100			
			1,023,500		
				22,000	
	Totals for Section	379,380	1,023,500	22,000	
15		36,000			
			639,700		
				37,400	
	Totals for Section	36,000	639,700	37,400	
	Below Section 15— Work at Hyde's Mill and Dam No. 1				
	Grand Totals	26,245,144	12,006,984	376,760	1,169,48

NO. 1—*Continued.*

version. Solid Rock.	Price.	VALUES—REGULAR CONTRACTS. *Main Channel.* Glacial Drift.	Solid Rock.	Retaining Wall.	*River Diversion.* Glacial Drift.	Solid Rock.	VALUES—COLLATERAL CONTRACTS.
							$ 632 44
							267 15
							59 35
							27 33
58,276		$ 7,935 75	$ 913,512 00		$ 7,578 25	$ 46,620 80	$ 48,549 55
	$0 30¼	$ 13,316 35					
	.79¼		$ 784,345 97				
	.30¼				$ 1,764 79		
11,268	.79¼					$ 8,929 89	
							$ 17,907 10
	.7055						14,113 82
	2.093						
							1,138 82
							1,000 00
11,268		$ 13,316 35	$ 784,345 97		$ 1,764 79	$ 8,929 89	$ 34,[illegible]59 74
	$0.30¼	$ 8,868 70					
	.30¼	3,772 17					
	.30¼	489 75					
	.30¼	191 18					
	.79¼		$ 775,209 24				
	.79¼		15,716 86				
	3.50			$ 32,445 00			
	.30¼				$ 3,551 05		
	1.196						$ 8,942 88
							7,541 87
							910 44
							300 00
							23 18
							56 12
		$ 13,321 80	$ 790,926 10	$ 32,445 00	$ 3,551 05		$ 17,774 49
	$0.26	$ 8,589 36					
	.26	200 98					
	.74¾		$ 753,835 06				
	.74¾		18,838 50				
	3.50			$ 37,933 00			
		$ 8,790 34	$ 772,673 56	$ 37,933 00			
	$0.20	$ 33,456 00					
	.36	76,356 00					
	.73		$ 747,155 00				
	3.50			$ 77,000 00			
		$ 109,812 00	$ 747,155 00	$ 77,000 00			
	$0.19	$ 6.840 00					
	.59		$ 377,423 00				
	3.40			$ 127,160 00			
		$ 6.840 00	$ 377.423 00	$ 127,160 00			
							$ 18,052 85
228,918		$7.538,965 32	$9,105.472 16	$1,251 642 25	$307.887 94	$174,506 75	$ 686,353 25

EXHIBIT B, TABLE NO. 1—*Continued.*

SUMMARY OF QUANTITIES.

For Summary of Values by Sections See Next Page.

	Cubic Yards.	Cubic Yards.
Glacial Drift, Main Channel—		
Regular Contracts	26,245,144	
Extra, Section 5, Collateral Contract	16,671	
Total Glacial Drift chargeable to Main Channel		26,261,815
Glacial Drift, River Diversion—		
Regular Contracts	1,169,484	
Collateral Contracts, Force Account, Section 1	158,617	
Collateral Contracts, Force Account, Section 2	89,718	
Collateral Contracts, Force Account, Section 4	106,803	
Collateral Contracts, Force Account, Section 5	12,256	
Collateral Contracts, Force Account, Section 11	6,893	
Collateral Contracts, for Spillway proper	4,713	
Collateral Contracts, near Spillway, Force Account	16,500	
Collateral Contracts, completing Levee, Section A	87,361	
Collateral Contracts, Muck in River, Section A	122,342	
Collateral Contracts, Extra Depth in River, Section A	21,225	
Collateral Contracts, Extra, J. Lehman, Section 1	10,162	
Total Glacial Drift chargeable against River Diversion		1,806,074
Total Glacial Drift, Main Channel and River Diversion		28,067,889
Solid Rock, Main Channel, Regular Contracts		12,006,984
Solid Rock, River Diversion—		
Regular Contracts	228,918	
Collateral Contracts, Force Account, Section 4	17,857	
Collateral Contracts, Force Account, Section 11	4,419	
Collateral Contracts, Force Account, Section 12	7,475	
Total Solid Rock chargeable against River Diversion		258,669
Total Solid Rock, Main Channel and River Diversion		12,265,653
Total Glacial Drift, Main Channel and River Diversion		28,067,889
Total Solid Rock, Main Channel and River Diversion		12,265,653
		40,333,542
Rubble Masonry (Retaining Wall), Regular Contracts		376,760
Slope Paving, Regular Contracts, Section 1		1,285

EXHIBIT B, TABLE NO. 1—*Continued*—SUMMARY OF VALUES—REVISED ESTIMATE OF JANUARY 1st, 1896.

Section.	Regular Contracts.			Collateral Contracts.				Regular and Collateral Contracts.		
	Main Channel.	River Divers'n.	Total.	Main Channel.	River Divers'n.	General.	Total.	Main Channel.	River Divers'n.	Total.
O	$ 344,784 35		$ 344,784 35	$ 2,500 00			$ 2,500 00	$ 347,284 35		$ 347,284 35
N	256,183 89		256,183 89					256,183 89		256,183 89
M	156,858 45		156,858 45					156,858 45		156,858 45
L	217,070 56		217,070 56					217,070 56		217,070 56
K	288,988 25		288,988 25					288,988 25		288,988 25
I	284,962 25		284,962 25					284,962 25		284,962 25
H	312,358 42		312,358 42					312,358 42		312,358 42
G	381,847 76		381,847 76					381,847 76		381,847 76
F	307,630 02	$ 37,580 58	345,210 60		$ 38,047 15		38,047 15	307,630 02	$ 75,627 73	383,257 75
*E	547,712 17	26,322 45	574,034 62		2,579 45	$ 190 01	2,769 46	547,712 17	28,901 90	576,804 08
D	623,459 76		623,459 76		2,880 54		2,880 54	623,459 76	2,880 54	626,340 30
C	443,534 54	41,348 96	484,883 50			1,360 71	1,360 71	443,534 54	41,348 96	486,244 21
B	425,743 56	57,371 22	483,114 78		400 00	1,680 12	2,080 12	425,743 56	57,771 22	485,194 90
A	792,405 98	39,330 16	831,736 14	220 60	76,190 97	6,736 03	83,147 60	792,626 58	115,521 13	914,883 74
1	1,129,195 57	1,586 52	1,130,782 09	2,763 91	175,388 05	1,019 79	179,171 75	1,131,959 48	176,974 57	1,309,953 84
2	857,809 10	8,264 48	866,073 58		55,005 68		55,005 68	857,809 10	63,270 16	921,079 26
3	837,477 17		837,477 17					837,477 17		837,477 17
4	1,018,349 54		1,018,349 54		79,910 23		79,910 23	1,018,349 54	79,910 23	1,098,259 77
5	756,330 50		756,330 50	14,501 17	6,736 54		21,237 71	770,831 67	6,736 54	777,568 21
6	684,628 51	32,078 16	716,706 67	16,055 65	8,588 41		24,644 06	700,684 16	40,666 57	741,350 73
7	726,051 39	57,138 39	783,189 78	11,044 05	10,568 75		21,612 80	737,095 44	67,707 14	804,802 58
8	890,269 84	89,355 27	979,625 11	5,358 52	40,868 39	3,209 60	49,436 51	895,628 36	130,223 66	1,029,061 62
9	791,838 28	23,573 72	815,412 00	1,012 30		3,000 00	4,012 30	792,850 58	23,573 72	819,424 30
10	921,447 75	54,199 05	975,646 80	86 68	40,046 80	8,416 07	48,549 55	921,534 43	94,245 85	1,024,196 35
11	797,662 32	10,694 68	808,357 00		34,159 74		34,159 74	797,662 32	44,854 42	842,516 74
12	836,692 90	3,551 05	840,243 95	966 56	16,484 75	323 18	17,774 49	837,659 46	20,035 80	858,018 44
13	819,396 90		819,396 90					819,396 90		819,396 90
14	933,967 00		933,967 00					933,967 00		933,967 00
15	511,423 00		511,423 00					511,423 00		511,423 00
Totals	$17,896,079 73	$482,394 69	$18,378,474 42	$54,509 44	$587,855 45	$25,935 51	$668,300 40	$17,950,589 17	$1,070,250 14	$19,046,774 82
Below Section 15						18,052 85	18,052 85			18,052 85
Total for all work under contract, Jan. 1st, 1896			$18,378,474 42				$686,353 25			$19,064,827 67

*Flood damages, $5,115.22, Section E not included, because charged against Streeter & Kenefick. Sections F, E and 1 are on basis of new contracts. See notes on these sections in body of Chief Engineer's Report for differences of cost between old and new contracts.

EXHIBIT B, TABLE NO. 3—SANITARY DISTRICT OF CHICAGO—ENGINEERING DEPARTMENT.

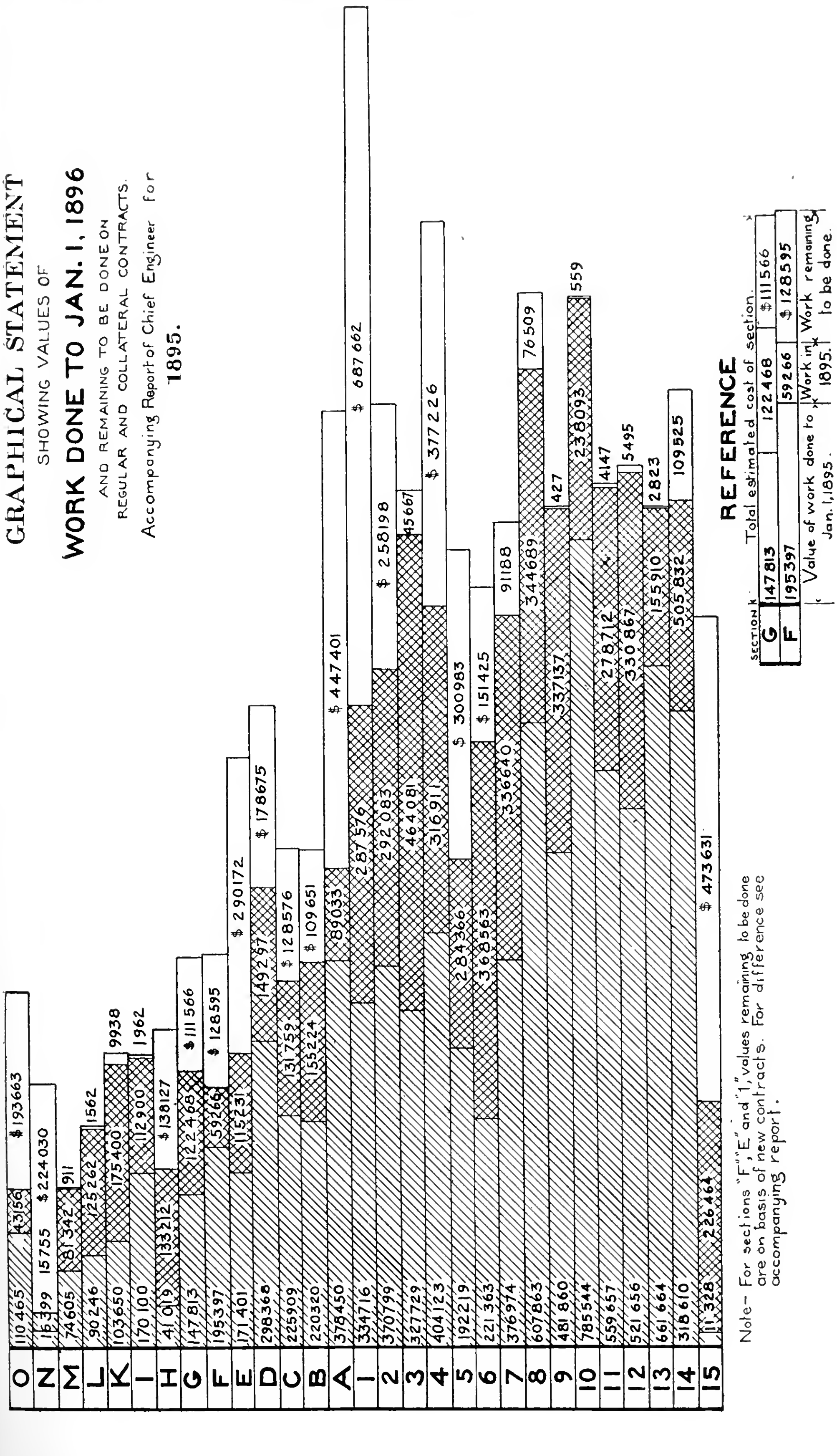
CLASSIFIED STATEMENT OF CUBIC YARDS OF MATERIAL EXCAVATED AND RETAINING WALL BUILT FROM THE BEGINNING OF WORK TO JANUARY 1, 1896.

SECTIONS.	1892.		1893.		1894.			1895.			TOTALS.			PRICE.
	Glacial Drift.	Solid Rock.	Glacial Drift.	Solid Rock.	Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	Retaining Wall.	Glacial Drift.	Solid Rock.	Retaining Wall.	
O					518,821			111,000			629,821			$0.21
					7,600			89,500			97,100			.199
N					71,300			68,500			139,800			.23
M					343,800			374,850			718,650			.217
L					458,100			635,850			1,093,950			.197
K					414,600			701,600			1,116,200			.25
I					680,400			451,600			1,132,000			.25
H					141,444			459,353			600,797			.29
G					527,906			437,385			965,291			.28
F			366,914		295,613						662,527			.2375
								200,900			200,900			.295
			4,713								4,713			.6990
			16,500								16,500			.7062
E			564,881								564,881			.275
					49,219			426,781			476,000			.27
D			227,317		890,555			564,528			1,682,400			.26 7-16
C			290,652		664,872			560,676			1,516,200			.235
B			204,626		604,477			574,097			1,383,200			.27
A					122,342						122,342			.15
			190,154		811,179			274,864			1,276,197			.30⅝
					86,000			1,361			87,361			.36
1			101,719		13,697						115,416			.27
					11,926						11,926			.30⅝
			10,162								10,162			.42
					301,700			436,500			738,200			.429
			158,617								158,617			.8653
									108,200			108,200		.80
										1,744			1,744	2.90

EXHIBIT B, TABLE NO. 3—*Continued.*

SECTIONS.	1892. Glacial Drift.	1892. Solid Rock.	1893. Glacial Drift.	1893. Solid Rock.	1894. Glacial Drift.	1894. Solid Rock.	1894. Retaining Wall.	1895. Glacial Drift.	1895. Solid Rock.	1895. Retaining Wall	TOTALS. Glacial Drift.	TOTALS. Solid Rock.	TOTALS. Retaining Wall.	PRICE.
2	24,700		32,400		2,091						59,191			.28
			63,400		483,452			132,373			679,225			.50
			89,718								89,718			.6131
						32,242			274,058			306,300		.80
										1,900			1,900	3.50
3	36,400		36,910								73,310			.27
			21,200		256,778			60,622			338,600			.56
						200,352			514,648			715,000		.76
										12,000			12.000	3.25
4	31,500		12,700		4,393						48,593			.27
			87,200		537,086			399,721			1,024,007			.49
			106,803								106,803			.502
						6,491			151,309			157,800		.80
				17,857								17,857		1.472
5	23,600		185,300		57,071						265,971			.27
					317 700			284,300			602,000			.31
			12,256								12,256			.5096
						15,100			153,300			168,400		.735
							1,300			25,710			27,010	3.25
6					24,100						24,100			.22
	18,200		229,800		381,500			127,300			756,800			.27
						43,100			320,300			363,400		.735
							1,300			27,200			28,500	3.25
7	29,800		134,700		102,100			3,717			270,317			.26
		500		107,700		297,000			420,200			825,400		.735
										5,800			5,800	3.25
8	54,800		5,600		37,800			9,302			107,502			.26
		12,840		159,260		546,800			440,200			1,159,100		.7475
										2,700			2,700	3.25
9	46,400		42,000		21,000			8,032			117,432			.26
		2,640		93,960		487,800			435,694			1,020,094		.769
10	46,200		7,100		3,300			5,456			62,056			.25
		20,350		253,550		630,800			294,767			1,199,467		.80

11			6,893								6,893			.7055
	34,100		11,956		3,732						49,788			.3025
		9,200		251,483		386,100			350,250			997,033		.7925
				4,419								4,419		2.093
12	15,553		11,847		11,739			15,131			54,270			.3025
		22,100		255,600		344,800			369,640			992,140		.7925
				7,475								7,475		1.196
										17.44			17.44	1.66
										9,152			9,152	3.50
13	32,822							600			33,422			.26
		30,700		327,300		515,700			156,700			1,030,400		.7475
										10,760			10,760	3.50
14	15,000		28,066		88.534			16,500			148,100			.20
					212,100						212,100			.36
		20,800		98,505		176,495			688,400			984,200		.73
15					29,500			2,600			32,100			.19
						9,700			383,000			392,700		.59
Totals	409,075	119,130	3,262,104	1,577,109	9,589,527	3,692,480	2,600	7,434,999	5,060,666	96,983.44	20,695,705	10,449,385	99,583.44	


GRAPHICAL STATEMENT
SHOWING VALUES OF
WORK DONE TO JAN. 1, 1896
AND REMAINING TO BE DONE ON
REGULAR AND COLLATERAL CONTRACTS.
Accompanying Report of Chief Engineer for
1895.
O 110465 43156 $193663
N 15399 15755 $224030
M 74605 81342 911
L 90246 125262 1562
K 103650 175400 9938
I 170100 112900 1962
H 41019 133212 $138127
G 147813 122468 $111566
F 195397 59266 $128595
E 171401 115231 $290172
D 298368 149297 $178675
C 225909 131759 $128576
B 220320 155224 $109651
A 378450 89033 $447401
1 334716 287576 $687662
2 370799 292083 $258198
3 327729 464081 45667
4 404123 316911 $377226
5 192219 284366 $300983
6 221363 368563 $151425
7 376974 336640 91188
8 607863 344689 76509
9 481860 337137 427
10 785544 238093 559
11 559657 278712 4147
12 521656 330867 5495
13 661664 155910 2823
14 318610 505832 109525
15 11328 226464 $473631
REFERENCE
Total estimated cost of section.
SECTION K
G 147813 122468 $111566
F 195397 59266 $128595
Value of work done to Jan. 1, 1895.
Work in 1895.
Work remaining to be done.
Note— For sections "F", "E" and "1", values remaining to be done are on basis of new contracts. For difference see accompanying report.

DISCHARGE OF THE MISSISSIPPI RIVER.

BY WILLIAM STARLING, M. AM. SOC. C. E.

(*Abstracts from Transactions of Am. Society C. E.*)

Estimation of Maximum Discharge.—In estimating, then, the maximum discharge which has passed down the Mississippi in a given year at Helena, it will not be proper to take the maximum discharge at Cairo and add to it the maximum discharge of the Saint Francis; and for Arkansas City, to increase this by the maximum discharge of the White and Arkansas. Such a process, in 1882, resulted in absurd overestimates; and, indeed, the discharge of that year has always been exaggerated. As it is a matter of great consequence to obtain correct information on this point, a revision of the figures which have been presented will be made.

At Columbus.—A probable value for the Columbus discharge was found from the observations of that year, to be 1,573,000 cu. ft. To this quantity a correction of 2 per cent should be applied for the defective formula, bringing the net discharge to about 1,540,000 cu. ft. This corresponds with the results of the Columbus and New Madrid obeservations of 1893, quoted on page 121. Besides this, there was an escape over the banks, estimated at 86,000 cu. ft. Reasons have been given for doubting or altogether discrediting these estimates, and the calculation on page 135, made from the New Madrid measurements of 1893, of 1,600,000 cu. ft. for the total discharge of 1882 at Columbus, including what passed outside of the channel, seems entirely reasonable. It may be affirmed that the measurements of 1893, checked at two points, made with the best instruments, by experienced men, and with the precautions shown to be necessary, and agreeing well together, taken, moreover, near extreme flood, are safe and trustworthy sources of information.

At Arkansas City.—The White River was at a stage of 21.8 ft. at Jacksonport when the crest of the rise passed the mouths of the two rivers; the Arkansas marked 15.1 ft. at Little Rock, and both were stationary, after having been much higher. It is likely, therefore, that they contributed nearly their full discharge, which was probably about 140,000 cu. ft. If 50,000 cu. ft. is added for the discharge of the Saint Francis, there will be about 1,790,000 cu. ft. for the volume which would have passed Arkansas City in a second in 1882 in a confined river. This estimate, however, is subject to deductions from several causes.

Deductions from Above Estimate.—The channel and flood plain of the river afford a considerable reservoir surface, to fill which will consume a portion of the discharge. This effect is particularly marked, as has been observed by Humphreys and Abbot,* toward the upper part of the alluvial valley, where the oscillations of height

*"Report on the Physics and Hydraulics of the Mississippi River," p. 371.

at the several gauge stations are sharper and more frequent. The effect, however, is cumulative, and the diminution of discharge continues as the river is descended. The extent of the reservoir influence will depend mainly on the duration of the rise. It is believed that an undue importance was attached to it by Humphreys and Abbot, who, reasoning from the experience of a short rise in 1858, estimated a regular loss of 140,000 cubic feet of discharge between Cairo and Helena. Such a loss may occur where a heavy and sharp flood comes out on a low river, and is succeeded by a rapid decline, but it cannot take place when the channel is already full and when the highest stage of the rise is prolonged for several days. Even under these circumstances, however, the reservoir influence is very perceptible. At Columbus, in 1882, the high stage of 102.8 feet lasted only for a single day. In four days more the river had fallen to 102.1 feet, and the discharge presumably from 1,600,000 to 1,560,000 cubic feet. Now it takes about four days in a confined river for the crest of the river to pass from Columbus to Helena. Taking the case of a confined river, and assuming the distance between levees when completed to be the same as already exists between Arkansas City and Wilson's Point, namely, about 2½ miles, the reservoir space at high water between Columbus and Helena will be about 712 square miles, or about 19,850,000,000 square feet. The rise at Helena in four days was about 1 foot. The river at Columbus will be supposed to be stationary (it varied from 102.62 feet to 102.79 feet). To fill the basin an average of 0.5 feet in one day would take about 10,000,000,000 cubic feet, or in four days about 2,500,000,000 cubic feet. This is equivalent to about 28,900 cubic feet per second. This much of the discharge therefore will be consumed in filling the reservoir during the process of raising the river at Helena 1 foot, and the discharge which passes Helena will be less than the discharge which has passed Columbus by so much. On the fifth day, the discharge will be reduced by the fall from above by about the same amount (from about 1,600,000 to 1,571,500 cubic feet), and the next day by as much more. As an approximation, the maximum discharge passing Helena in 1882, in a confined river, would have been nearly 30,000 cubic feet per second less than passed Columbus. At Arkansas City, by the same mode of reasoning, the loss would have been increased to about 42,000 cubic feet, at Wilson's Point to 52,000 cubic feet.

Experience with confined waters at time of extreme flood is very limited. That condition is usually soon disturbed by crevasses and other complications. It is a time of great activity, anxiety and worry, and accurate observations of the behavior of the river are scarce. With such unknown conditions, it is possible that unexpected phenomena may be developed, causing an increased discharge to pass at very high stages. From causes which are already known, it is likely that flood heights at such stages will be diminished still further below the estimates given.

First.—No account has been taken of the discharge over banks

or between the margin of the river on either side and the adjacent levee. The average distance between levees, as has already been remarked, from Arkansas City and Wilson's Point, is about 2½ miles, of which space the river occupies nearly one-third. The levees are something like 12 feet high. As the flood water gets deeper over these "fore-shores," its velocity will increase rapidly. Even now, the "over-bank discharge" is an element which must be taken into account in every set of high-water measurements. At Arkansas City, in 1893, at the highest stage, this was estimated at 9,000 cubic feet, and at Wilson's Point it was over 30,000 cubic feet. Of course, the influence of this element will not be confined to the local space at each point that may lie between the levee and the river, but will depend on the general section or the controlling section, whatever it may be.

Second.—At high stages the river flows between "water banks," as is often expressively said, for the upper part of its section, namely, that which is over bank-full height. Thus the friction and local disturbance ought to be somewhat diminished. It is not easy to estimate accurately the value of this element, but it would probably be not very great. In the ordinary formula, the substitution of banks of water for banks of earth for the upper 10 feet of the section, even supposing the "water banks" to exert no resistance at all, would make a difference of only about 0.02 feet per second in the velocity, or say 5,000 cubic feet in the discharge.

Third.—It has been seen that it is possible for serious permanent alterations to occur in the bed of the river, and that the slope also undergoes modifications. This simply means that the river is relatively lower at some points than it used to be, as compared with the standard, Arkansas City. The confinement of the river, more or less complete, might be expected, indeed, to produce some effect on the bed. If a deterioration of the latter was brought about by the loss of volume over the banks, then it might reasonably be hoped that the retention of the water formerly lost by dispersion would have the effect of lowering the bottom in those places, so as to conform more nearly to the high-water slope.

Very sanguine expectations have been entertained of the scouring action of the powerful high-water forces thus brought into play. As the river never has been completely restrained, it cannot be said that the experiment has yet been fairly tried. The enlargement of cross-section at Wilson's Point, previously noticed, seems to have occurred in one season, from 1890 to 1891, and it has changed but little since that time. If the slope Arkansas City-Greenville has steepened, the slope Greenville-Lake Providence seems to have flattened a little. The relation between the gauges at Arkansas City and Lake Providence appears to have undergone no considerable alteration since 1885. The section at Arkansas City, with all its temporary mutations, remains the same. The discharge does not pass at a materially lower height than might have been predicted

from the experience of previous years. So far, in the part of the river considered, the hopes entertained have not been realized.

Revised Estimate.—For all these causes, it seems reasonable to suppose that the extreme discharge of 1,790,000 cubic feet found for Arkansas City in 1882 would have been diminished by at least 55,000 cubic feet, perhaps more, and that the maximum actual discharge which would have passed in a confined stream in that year would have been not greater than 1,735,000 cubic feet. This would require, by the methods previously used, a gauge height of about 55.8 feet.

It will be well to compare the floods of more recent years, and see whether the high water of 1882 was really the greatest of which there is any record, and consequently whether it was correctly adopted as a standard.

In 1883, the river attained its greatest recorded height at Cairo. There was a considerable flood in the Arkansas and White Rivers, but it did not coincide with the crest of the main rise. The river below Arkansas City was at an unusually depressed stage when the rise began; so the reservoir capacity of the channel was very great. Consequently the flood wave flattened out, and the gauge at Vicksburg was 5 feet lower than in 1882.

The flood of 1884 was one of the greatest ever known. It may fairly be compared with 1882. The gauge at Cairo and at Helena was nearly the same as in 1882. At Vicksburg it was 0.15 feet higher. No material change had occurred in the situation. No discharges were taken in 1884, and it is not easy to institute minute comparisons between them.

In 1886, there was a short and sharp rise which reached 51 feet at Cairo and 48.1 feet at Helena, the levees of the upper Yazoo District having been recently rebuilt. There were no serious freshets from the White and Arkansas Rivers, and the river at Vicksburg was 4.6 feet lower than in 1882.

There was a great flood in 1890. It was not very high at Cairo, only 48.8 feet, but it was very long and persistent, and it was accompanied by an unparalleled stage of White River, which stood for four months at a mean height of 26 feet at Jacksonport, the highest being 33.2 feet (the greatest on record), and the lowest 20 feet. The Arkansas was not so high, but was above medium stage most of the time. There were two great freshets of the tributaries, the former and greater of which occurred before the Mississippi had reached its height. The second took place in April, after the main rise, but during the later rise which succeeded the first, which was nearly as high. The mean of twelve consecutive days at Helena gives a discharge of about 1,470,000 cubic feet (reduced) at an average stage of 47.24 feet, with a crevasse 19 miles above, discharging about 30,000 cubic feet. The Arkansas and White Rivers no doubt added some 200,000 cubic feet to this volume, making in all about 1,700,000 cubic feet. There were many breaks in the levees on both sides of the river.

The flood of 1892 reached a height at Cairo of only 48.3 feet, and remained there only a short time. The year would not have been remarkable had it not been for the tremendous outpour of the Arkansas, accompanied by a very high stage of White River, shortly before alluded to, which made it extremely formidable, and would indeed have made it disastrous to the levees had it not been for the escape of a large part of the waters of the Arkansas around the head of the Tensas Basin system. The discharge at Columbus is given as about 1,380,000 cubic feet for a mean of five days, but as the velocities were taken at six-tenths depth, a correction should be applied, which, at Columbus, would amount to 5 per cent or so. At Helena, for six days, the discharge is reported as 1,302,000 cubic feet, but as the meter had not been rated during the season, the results here and at Columbus cannot be relied on. The Arkansas City discharges taken at and after the height of the rise seem to be free from the disturbing influences which had caused so much trouble earlier in the season, and are coherent and consistent with the measurements of the succeeding year. For a mean of ten days at the top of the flood, the discharge is given as about 1,450,000 cubic feet; corrected for six-tenths depth, by the factor habitually used in 1893 at Arkansas City, about 1,425,000 cubic feet. The overflow around the end of the levee and through breaks along the Arkansas River was estimated at about 280,000 cubic feet. These estimates are always too great. Doubtless the total discharge was between 1,650,000 and 1,700,000 cubic feet.

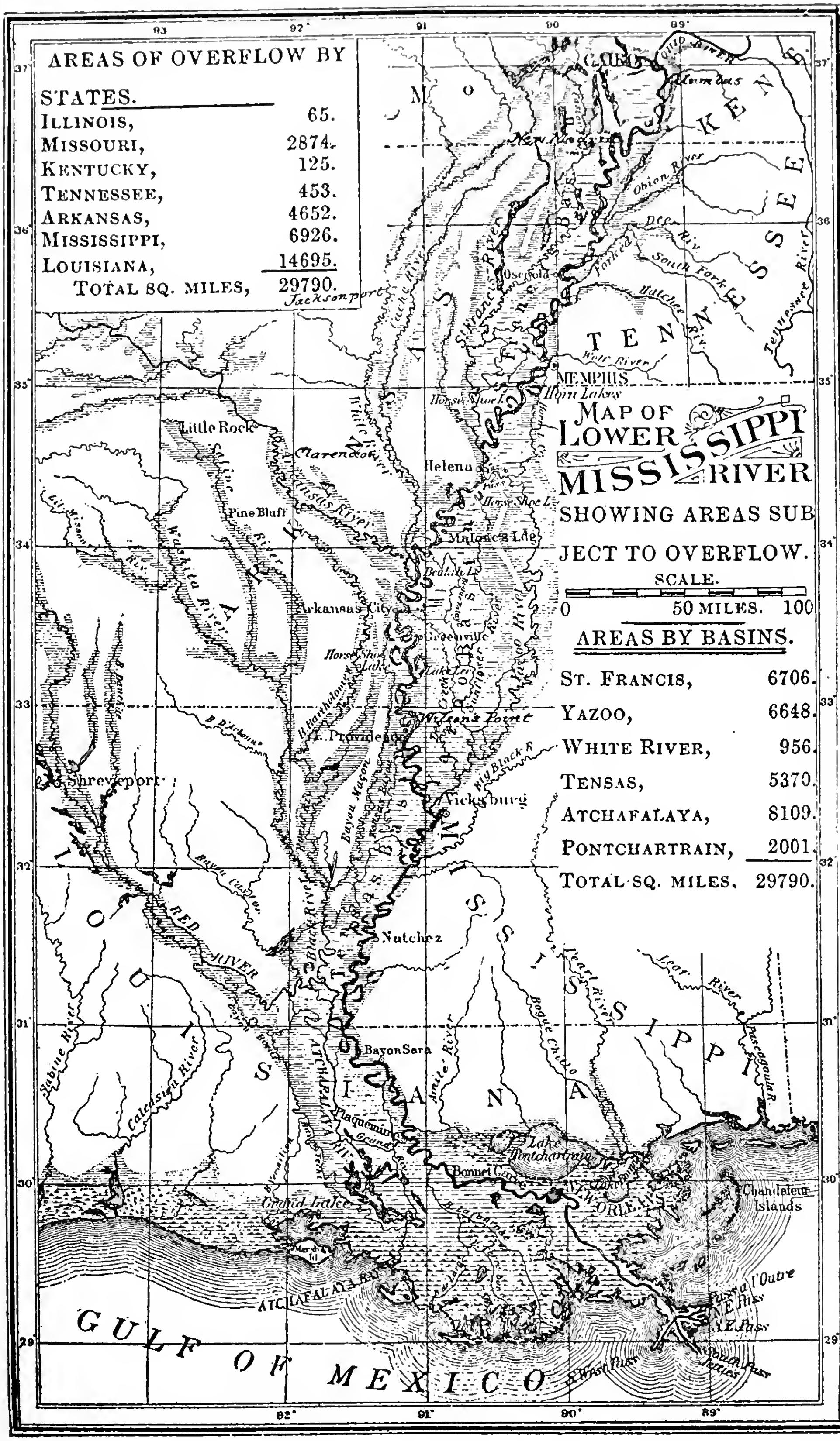
The flood of 1893 has been pretty thoroughly discussed. The total discharge passing Arkansas City would no doubt have been about 1,600,000 cubic feet.

It is now possible to answer the question propounded on page 129, which was the cause of the discussion of the effect of reservoirs on the discharges of tributaries, namely, whether the increased gauge height produced at Helena by the confinement of the river would be propagated down stream. In 1882, at Arkansas City, the height would have been about 55.8 feet, and the discharge of the two tributaries would have increased the gauge height at Arkansas City about 3 feet over that of Helena. It was thought probable that the latter would have been, in a confined river, about 53 or 53.5 feet (see pages 129 and 135). The conclusion is that the increased gauge height at Helena would extend its influence to the other gauges further down stream.

These inferences might be substantiated by reasoning drawn from the relations between the gauges. This part of the subject, however, has already been well and thoroughly discussed by others.

LOW-WATER DISCHARGE.

Comparatively little attention has been paid to the low-water discharge. Very few observations have been taken at that stage. The least discharge recorded in the reports of the Mississippi River

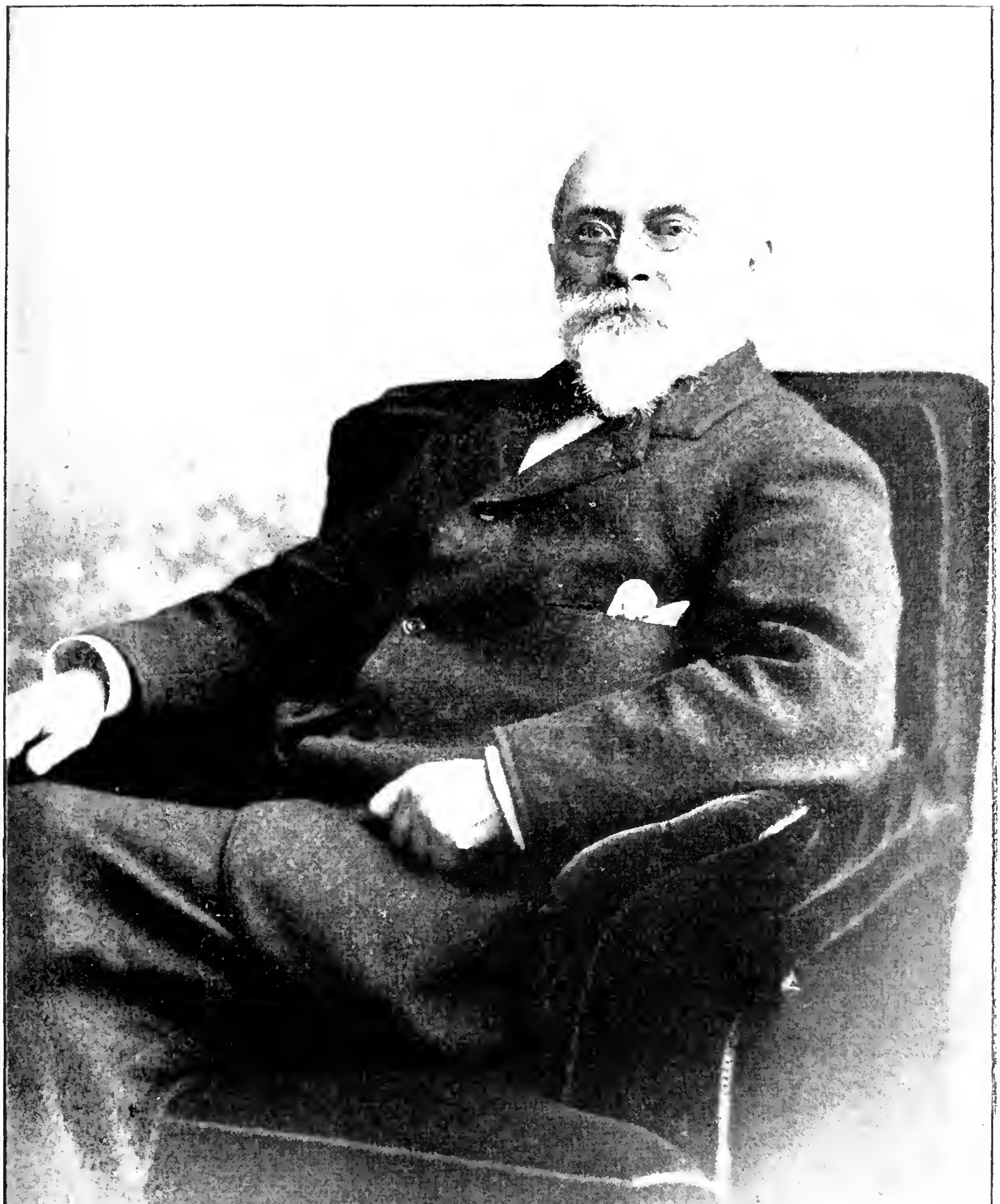

AREAS OF OVERFLOW BY STATES.
ILLINOIS, 65.
MISSOURI, 2874.
KENTUCKY, 125.
TENNESSEE, 453.
ARKANSAS, 4652.
MISSISSIPPI, 6926.
LOUISIANA, 14695.
TOTAL SQ. MILES, 29790.
MAP OF LOWER MISSISSIPPI RIVER
SHOWING AREAS SUBJECT TO OVERFLOW.
SCALE.
0 50 MILES. 100
AREAS BY BASINS.
ST. FRANCIS, 6706.
YAZOO, 6648.
WHITE RIVER, 956.
TENSAS, 5370.
ATCHAFALAYA, 8109.
PONTCHARTRAIN, 2001.
TOTAL SQ. MILES. 29790.
CAIRO
Ohio River
Columbus
New Madrid
Osceola
MEMPHIS
Horn Lakes
Helena
Little Rock
Pine Bluff
Clarendon
Jacksonport
Arkansas City
Greenville
Wilson's Point
Vicksburg
Shreveport
Natchez
Bayou Sara
Plaquemine
Lake Pontchartrain
Bonnet Carré
NEW ORLEANS
Grand Lake
Chandeleur Islands
Pass a l'Outre
Red River
Atchafalaya Riv.
Pearl River
Yazoo River
GULF OF MEXICO

Commission was in the fall of 1891. In November of that year, at a gauge reading of 2.9 feet at Cairo, the discharge was reported as 114,203 cubic feet. At Elmot Landing, in Plum Point Reach, near the same time, the mean of the four lowest days was about 81,400 cubic feet. At Memphis, at an equally low stage in October, it was reported as about 91,000 cubic feet. At Helena, the lowest record, both in October and in November, for the mean of several days, was about 106,000 cubic feet at a stage of zero. At Wilson's Point, in November, there was a minimum discharge reported (one observation only) of 117,142 cubic feet. At Red River Landing, the lowest record was 141,179 cubic feet.

The observations of the last four years have shown a perceptible depression of the low-water plane at Wilson's Point, as will be seen by the following table:

Year.	Gauge.	Discharge.
1891	5.00 ft.	133,000 cu. ft.
1892	4.7 ft.	145,000 cu. ft.
1893	2.1 ft.	156,000 cu. ft.
1894	2.3 ft.	177,000 cu. ft.

In 1894, this depression was general, and extended at least from Memphis to Vicksburg, the low-water record having been broken at every intermediate point. That this was not due to the small quantity of water flowing in the river is shown by the discharge at Wilson's Point, which was greater than in 1891. What significance is to be attached to this phenomenon is not yet known, and probably further observation will be required to develop it. It may not be permanent. It is to be observed that the stage in 1894 was very nearly paralleled in 1872 at Memphis and at Lake Providence for a day or two. The low water of 1894, however, was far more persistent, the gauge at Vicksburg remaining below zero for nearly three months.



WILLARD SMITH POPE.

WILLARD SMITH POPE.

A MEMOIR.

Mr. Willard Smith Pope was born on the 16th of January, 1832, in the then village of Rome, N. Y., and died at Detroit, Mich., Thursday, October 10, 1895. He was the son of Dr. G. W. Pope, a physician, and a man of standing in the community. His early life was spent in Rome, where he attended school and prepared for college. He entered Hamilton College, Clinton, N. Y., in 1847, and graduated in 1851, at the early age of nineteen. After graduation he went to Buffalo, where he studied law, and was admitted to the bar after a single year of hard work. The early labor by which he had accomplished this result at a period when boys are often still at school, now told upon him and his health gave way. He left Buffalo, returned to his father's home in Rome, and spent several months in the open air under the general care of his father.

Feeling that his health required an outdoor life he obtained a position in the engineer corps of the European & North American Railway, and spent the fall of 1852 and the following winter in the woods of New Brunswick and Maine. This was the beginning of his work as an engineer, and he decided to abandon the law and make engineering his profession. He next spent the larger part of a year in the Astor Library in New York City laying a theoretical groundwork for his new profession. In 1853 he came to the west and worked for the Illinois Central Railroad on the location of its line in southern Illinois. From there he went in 1854 to the Chicago & Galena Union Railroad, which in 1864, by a consolidation with other lines, became the Chicago & Northwestern Railway. He remained here till the latter part of 1864, and during the last four or five years he held the position of chief engineer.

It was while here that he was called on to do his first important work in bridge-building. The bridge across the Mississippi River at Clinton was the second bridge across that river, the only earlier one being the old Rock Island bridge, the piers of which were founded on rock in shallow water. No such rock existed at Clinton, and the river was narrow and exceptionally deep. Mr. Pope used pile foundations, which has since become the standard practice on the upper Mississippi, for all the piers except the pivot pier and founded the pivot pier on a timber crib 400 feet long, which not only carried the pier but formed the draw protection. The same pier is still in good condition on the same foundation.

The draw of the Clinton bridge was the first iron draw of importance built in the west. It consisted of two spans of Bollman trusses hung by hog chains from a central tower. It was built by contract by the Detroit Bridge & Iron Works. This contract shaped the remainder of Mr. Pope's life. He resigned his position as chief engineer of the Chicago & Galena Union Railroad, associated him-

self with the Detroit Bridge & Iron Works, and was elected a director of that company on February 9, 1866. He opened an office in Chicago and remained there a year as the representative of the bridge works; he then went to Detroit and took direct charge of the engineering department. On May 7, 1869, he was elected president of the company and held this office until his death.

Mr. Pope's connection with this company, covering a period of nearly thirty years, so completely identified the man and the corporation that no life of Mr. Pope is complete which does not include a history of the bridge works. The Detroit Bridge & Iron Works was incorporated in the year 1863, and succeeded to the business of the bridge-building firm of Charles Kellogg & Company, this firm consisting of Mr. Charles Kellogg, now deceased, and Mr. William C. Colburn, who is still treasurer of the company. As early as 1861 this firm had constructed iron bridges on the Illinois Central Railroad and on the Chicago & Galena Union Railroad; they were of the Bollman pattern, and may be considered the pioneer iron bridges built in the west.

From February, 1866, to the time of his death, with occasional short vacations, Mr. Pope gave the most thorough personal supervision to all the work constructed by this company. In 1866 the Detroit Bridge & Iron Works took the contract for the superstructures of the bridges at Burlington and Quincy, these being the first two all iron bridges built across the Mississippi River; they also contained the first draw bridges of what may be called modern dimensions, and Mr. Pope's ability as an engineer was strikingly illustrated in the special features of these draws; their turntables were far in advance of any others built up to that time, and they were equipped with a system of lifting cams at the ends which are still as good as anything in use; both these bridges were opened for traffic in 1868.

In 1869 and 1870 the Detroit Bridge & Iron Works built the bridge across the Mississippi River at Hannibal, taking the entire contract for both substructure and superstructure, the first time this had been done on any great western bridge. Subsequently the same company took the contract for the bridge across the Missouri River at St. Joseph, which was opened in 1873, building the entire substructure and superstructure. Col. Eddy D. Mason, since deceased, was the chief engineer of both of these bridges, and they are both monuments of the skill of the engineer proper and the engineering contractor. Although no bridges of equal magnitude were subsequently built complete by the Detroit Bridge & Iron Works, the company has continued steadily in the bridge business, confining itself principally to superstructure. Its shops at Detroit have always ranked among the best class of bridge shops, and engineers have always felt that Mr. Pope intended to furnish the best work his shops could produce.

Among the last important works constructed by this company

may be mentioned the Ferris Wheel for the World's Columbian Exhibition and the steel gates for the new lock on the St. Mary's Falls Canal.

While his life work greatly exceeded that done by most men, Mr. Pope never fully recovered from the breakdown of his early years.

Few men had warmer friends than he. The associates of his early years on the Chicago & Galena Union Railroad describe him as the most genial of companions, full of sparkling wit. During his residence in Detroit he held a position which seldom belongs to an engineer; at public dinners he was sought after as the brightest and wittiest speaker of the place.

Mr. Pope was married three times. In 1856, to Miss Harriet L. Bissell, daughter of Dr. Emory Bissell of Norwalk, Conn; she died in the following year. In 1861, he married Miss Julia Bissell, a sister of his first wife; she died in 1872. In 1882, he married Mrs. Martha E. Patterson, widow of Philo M. Patterson of Detroit, and daughter of W. H. A. Bissell, Bishop of Vermont, and who survives him. He leaves three daughters and one son, all of whom, with his widow, reside in Detroit. His son, Willard Pope, has followed his father's profession, and is now an engineer with the Detroit Bridge & Iron Works.

Mr. Pope became a member of the American Society of Civil Engineers August 7, 1872. He was elected a director in January, 1893, and had nearly completed his term of office at the time of his death.

Mr. Pope was a charter member of the Civil Engineers' Club of the Northwest, which was organized in 1869 and merged into the Western Society of Engineers in 1880. He was president of the Western Society of Engineers from January 2, 1882, to January 8, 1883, and was the only non-resident member ever elected to that office.

The following account of Mr. Pope, which shows the social and literary side of his character, appeared in the Detroit Free Press on the day after his death:

"It used to be thought that history was an account of what kings and warriors did, and it is still far too much the fashion to regard the doings, the lives and deaths of those in public life as of paramount importance. But when a man like Willard S. Pope drops out of the ranks of private life we feel that the event affects the community quite as seriously as the loss of a recognized leader.

"Modest and retiring almost to a fault, Mr. Pope was well known to comparatively few; but within the circle of his acquaintance he was esteemed and loved as it is not given to many men to be. The attachments that he formed were deep and lasting. Once a friend with him was always a friend, and his friendship was no empty form. He had the faculty which is rarer than is sometimes thought of perfect earnestness. He hated sham and pretense as the good hate everything that is low or mean or vile, and his associates appreciated this quality at its full value.

"Socially, Mr. Pope was one of the most delightful of men. Al-

ways chary about asserting himself, he had to be drawn out, but the drawing process disclosed his possession of a fund of the quaintest humor which became on occasion exceedingly bright and sparkling. He was especially happy in a certain affectation of cynicism, which was oddly at variance with his real habit of thought, and used it very effectively in the puncturing of shams that was somewhat of a passion with him. He was always, however, tenderly careful of the feelings of others, and resented with all the force of his really strong nature the reckless habit into which so many have fallen in recent years of trifling in speech and otherwise with the reputation of others. He was not given as a rule to impassioned utterances; but those who knew him best will recall more than one occasion when he indulged in it in denunciation of criticisms upon individuals which he deemed unwarranted, inexcusable and slanderous.

"Had Mr. Pope given his attention to literature he would have made for himself an exceedingly enviable place in the ranks of writers. He had a style of his own, and his occasional efforts, some of which in the shape of correspondence from foreign lands adorned the columns of the Free Press, attracted a great deal of attention and were greatly praised. Literature was, however, only a pastime with him; what he regarded as his real work lay in another direction in his chosen profession.

"Peace to his ashes. There are not a great many men whom the community could so ill spare."

GEO. S. MORISON,
E. C. CARTER,
L. P. MOREHOUSE,
Committee.

Western Society of Engineers,

ROOMS, 1737 MONADNOCK BLOCK,

CHICAGO, ILLS

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FIRST VICE-PRESIDENT,
THOS. T. JOHNSTON.

SECOND VICE PRESIDENT,
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EMIL GERBER.

SECRETARY,
HENRY GOLDMARK.

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W. L. STEBBINGS, G. M. BASFORD,
A. M. FELDMAN, G. L. CLAUSEN,
W. D. HOTCHKISS.

ENTERTAINMENT COMMITTEE,

GEO. P. NICHOLS,
C. E. SCHAUFFLER,
T. L. CONDRON.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1895.

To the Western Society of Engineers:

At the last Annual Meeting of the Society, January 2, 1895, the Secretary reported a total membership, including those recently elected but not qualified, of....		416	
The number of members-elect who had not qualified was..		24	
The actual membership of the Society at that time, as shown by the records, was as follows:			
Honorary Members..................................	1		
Members	371		
Juniors	1		
Associates	19		
Total actual membership January 2, 1895................			392
The additions to the membership have been:			
Elected previous to Annual Meeting January 2, 1895, and since qualified	20		
Elected and qualified January 2, 1895, to January 8, 1896...	32		
Delinquents reinstated	2		
			54
Total enrollment January 2, 1895, to January 8, 1896.....			446
Losses—By deaths	4		
By resignation	14		
Dropped January 5, 1895, for delinquency of dues for 1894..............................	13		
Dropped December 31, 1895, for delinquency of dues for 1895..............................	16		
Total losses			47
Membership January 8, 1896.....................			399
Comprised of:			
Resident Honorary Members.....................	1		
Resident Members	259		
Resident Juniors	3		
Resident Associates	20		
Non-resident Members	113		
Non-resident Associates	3		
	399		

During the year one Junior was transferred to the grade of Member, and seven members-elect have not yet qualified.

The losses by death during the year 1895 have been:

William A. Hammett, who died in March.

Warren Collier Smith, who died March 29th.

Gen. Orlando M. Poe, who died October 2d.

Willard S. Pope, who died October 10th.

Memoirs of Gen. Poe and Mr. Pope will appear in the new Journal of the Society.

The fourteen resignations above noted are the following: Members—Dorsey Ash, Frank M. Button, Leverett H. Clarke, J. D. Cook, Chas. A. Hasbrouck, Chas. E. Hopkins, Herbert F. Northrup, Theodore Starrett, Luther Thompson, John L. Van Ornum and Nelson O. Whitney. Associates—Arthur E. Bingham, Chas. A. Marsh and Frank Wenter.

The following-named candidates were elected to membership in the Society, December 3, 1895 (not previously reported): As Members—Carl Haller, Wm. T. Keating, LeRoy K. Sherman and Leland L. Summers.

At the Annual Meeting of the Board of Directors, January 7, 1896, the following-named candidates were elected to membership: As Members—John C. Ostrup. As Junior—Stillman B. Jamieson. As Associates—James W. Gardner and Joseph S. Qualey; and the following applications for membership were received and placed on file: As Members—Robert Carter Berkeley, Jr., Henry Morton Brinckerhoff, Byron B. Carter, John Waterbury Crissey and Samuel French Nichols, all of Chicago. As Junior—Marion Ellis Thomas, Chicago. As Associate—James O. Winston, Willow Springs, Ill.

Early in the year a lease for three years from May 1, 1895, was taken of rooms 1736 to 1739, Monadnock Block, and the new quarters were occupied January 29, free of rent until May 1.

The first meeting of the Society in the new rooms, March 6, was made the occasion of a house warming. About 125 members and guests were present. The meetings of April 3 and June 5, in the Society's rooms, were also given a social character, and were much enjoyed by those present.

The cordial invitation of the Directory and Faculty of Armour Institue of Technology, for the Society to hold meetings at the Institute, with the generous offer to place at the command of the Society all appliances for electrical illustration of lectures and papers, including the preparation of as many lantern slides as were deemed requisite, was accepted, and the first meeting at the Institute was held February 6, 1895, in Science Hall, preceded by an inspection of the Institute and followed by a practical test of the utility of the Institute "Department of Domestic Arts"—light refreshments.

To Professor Frank C. Hatch, Director of the Department of Mechanical Engineering, a member of the Society; to Professor Wilber F. Stine, Director of the Department of Electricity and Electrical Engineering, and to Mr. John E. Snow, Assistant to Professor Stine, who prepared and exhibited at the meetings the large number of lantern slides required for illustrations, the Society is especially indebted.

Six meetings were held at Armour Institute during the year, with an attendance ranging from 150 to 36, averaging 77. Twelve meetings were held in the Society's rooms (two being adjourned meetings), the attendance ranging from 125 to 14, averaging 43; an average attendance for the eighteen meetings of 54.

The Committee on Publications and Papers, Mr. G. A. M. Liljencrantz, Chairman, and Messrs. David L. Barnes and L. P. Morehouse, members, gave much time during the year to securing papers to be read and in arranging for informal "talks" before the Society on subjects of interest, in lieu of written papers, and in the subsequent review of papers and illustrations before their publication in the Journal of the Association of Engineering Societies.

The following professional papers were read during the year:

Nos. 1 and 2. February 6th. "The Chicago Sanitary District Canal," "Description of the Work and Methods of Construction on the Brighton Division," by Mr. Alex E. Kastl, Division Engineer, M. W. S. E. Published, April, 1895.

"Description of the Work and Methods of Construction on the Summit Division," by Mr. E. R. Shnable, Division Engineer, M. W. S. E. Published, June, 1895.

No. 3. March 20th. "The Van Buren Street Rolling-lift Bridge," by Mr. Warren R. Roberts, City Engineer of Bridges, M. W. S. E. With discussion. To be published in the Journal for December, 1895.

No. 4. April 17th. "The Highway Bridges Across the Mississippi River," by Mr. Horace E. Horton, President W. S. E. Not yet published.

No. 5. May 14th. "The DeKalb Electrical Pumping Plant," by Mr. Daniel W. Mead, M. W. S. E. With discussion. Published, August, 1895.

No. 6. September 24th. "Notes on the Dry Docks of the Great Lakes," by Mr. A. V. Powell, M. W. S. E. To be published in Vol. 1, No. 1, of the Journal of the Western Society of Engineers.

No. 7. November 21st. "Applications of Electrical Power to Industrial Purposes," by Mr. Geo. P. Nichols, M. W. S. E. With discussion. Not yet published.

No. 8. December 19th. "Engineering Consequences of the Waterway Conventions at Cleveland, Ohio, and Vicksburg, Miss., 1895," by Mr. Thos. T. Johnston, M. W. S. E. With discussion. Not yet published.

All these papers except the last one mentioned were read at Armour Institute of Technology, and were illustrated by large numbers of lantern views specially and most generously prepared by the Institute without any expense to the Society.

In addition to the above papers read during the year, four other papers—read during the previous year—were placed in the hands of the Committee and subsequently published in the Journal of the Association of Engineering Societies. They are as follows:

No. 1. "The Chicago Sanitary District Canal—Introductory," by Mr. Isham Randolph, Chief Engineer, M. W. S. E. Published, March, 1895.

No. 2. "Notes on a Broken Pinion Shaft," by Mr. Onward Bates, M. W. S. E. With discussion. Published, March, 1895.

No. 3. "Carbon Dioxide for Refrigeration and for Extinguishing Fires," an abstract of a paper "Refrigeration by Carbon Dioxide," by Mr. E. F. Osborne, M. W. S. E. Published, March, 1895.

No. 4. "Strains and Deflections in Solid Bridge Floors," by Mr. Henry Goldmark, M. W. S. E. With discussion. Published, August, 1895.

One other paper of the series on the Chicago Sanitary District Canal—"General Hydraulics of the Chicago Main Drainage Channel," by Mr. Thos. T. Johnston, Assistant Chief Engineer, M. W. S. E., was read in 1894, but has not been received for publication.

Besides the above named regularly prepared papers, the Society has been favored with three very interesting informal "talks," eliciting quite lively discussion. They were as follows:

October 2d. "The Proper Chemical Composition of Steel for Heavy Rail Sections," by Capt. Robt. W. Hunt, M. W. S. E.

November 6th. "Methods of Power Testing of Motocycles," by Messrs. John Lundie and L. L. Summers, members W. S. E.

December 4th. "Oriental Railways," by Mr. Clement F. Street, Manager The Railway Review; by invitation. Mr. Street's interesting talk was reported and will appear in Vol. 1, No. 1, of the Journal of the Western Society of Engineers.

RECAPITULATION.

Papers read in 1894; published in 1895	4
Papers read in 1894; not yet received for publication	1
Papers read and published in Journal for 1895	4
Papers read in 1895; not yet received for publication	4
Total number of papers read in 1895	8
Total number of papers published in Journal for 1895	8
Number of informal "talks"	3

As previously stated, some of the above will appear in the new Journal of the Western Society of Engineers.

Under direction of the Excursion and Entertainment Committee (Mr. E. Gerber, Chairman, and Messrs. Ralph Modjeski and Geo. P. Nichols, members), inspection trips and excursions to various places of engineering interest were made during the year; the first one being an inspection by some seventy-five members and guests of the new VanBuren street rolling-lift bridge, March 16th, by invitation of Mr. Samuel G. Artingstall, City Engineer and Past President of the Society. The Metropolitan West Side Elevated Railway bridge, adjacent, was also visited by invitation of Mr. Wm. M. Hughes, principal Assistant Engineer.

April 27th, by invitation of Mr. James R. Chapman, manager of the electrical department of the North Chicago Street Railway Company, a

visit to and inspection of the power house of the North Chicago Electric Transit Company was participated in by about forty members and guests.

On May 18th, a trip was taken over the Metropolitan West Side Elevated Railway, by invitation of Mr. W. E. Baker, General Superintendent.

The rolling-lift bridge over the south branch was first inspected, when the party of 108 members and guests of the Society were taken by special train over the main line to West Forty-eighth street, the power house being inspected on the return trip.

The Annual Pleasure Outing of the Society was an excursion to Milwaukee by the steamer Indiana, Monday evening, August 5, 1895, arriving Tuesday morning. The attendance was not large, but the trip was a very enjoyable one. During the forenoon the party visited the new Sixteenth street viaduct and Bascule bridge, the shops of the Edward P. Allis Company and the Chicago & Northwestern Railway drawbridge, operated by a gas engine. In the afternoon carriages were taken for a drive about the city under escort of Mr. M. G. Schinke, Assistant City Engineer, visiting the new City Pumping Works. Return to Chicago was by steamer Virginia, on Tuesday evening.

The invitation of the Chicago Ship Building Company, through its General Manager, Mr. W. I. Babcock, member of the Society, for the Western Society of Engineers, to be present at the launching of the steel steamer Zenith City, on Wednesday afternoon, August 14, 1895, was accepted by about seventy-five members and their friends. By courtesy of Messrs. Shailer & Schniglau and the Fitz Simons & Connell Company, their respective tugs were placed at the disposal of the Society for that afternoon, to take its members to the shipyard and return. Refreshments were provided on the boats.

On Saturday, October 12th, a very delightful excursion was made to various points of interest on the Chicago Sanitary Drainage Canal. By the courtesy of the Chicago & Alton Railroad Company a special train was secured, and a luncheon was served on the train. About 225 members and guests, including many ladies, participated.

On November 9th, by invitation of the Pioneer Rail-renewing Company of Chicago, a considerable number of members visited the works of that company to view the process of re-rolling old rails. The Gates Iron Works were also visited and the system of operation was fully inspected.

All of the above trips were made without cost to the Society, and the Entertainment and Excursion Committee has made all arrangements for the Annual Banquet.

At the beginning of the year, after payment of bills approved at the annual meeting of the Board of Directors, January 2, 1895, there was in the Treasury a cash balance of $413.92. Of this sum, $297.50 was prepaid dues for 1895, and $83.18 an unexpended balance of the library fund, leaving $33.24 to the credit of the general fund.

The detailed statement of receipts and expenditures to December 31, 1895, is given in the appendix.

During the past year, owing to the amount of indispensable routine work of the office, the Secretary has been unable, greatly to his regret, to do much in his capacity as Librarian. A considerable number of periodicals have been received from various sources, and in April last 89 volumes of periodicals were bound, at a cost of $107.75. Shelving for 1,000 to 1,200 volumes was also provided. The Society is greatly indebted to a committee of the Board of Directors, Messrs. Liljencrantz, Johnston and Barnes, and to Messrs. James J. Reynolds, Carl E. Davis, E. Gerber and Frank P. Kellogg, members of the Society, for their very efficient service in the interest of the Library, and to Mr. O. Chanute and other members and friends, for valuable gifts of books, etc.

The most important action taken by the Society during the past year has been our withdrawal from the Association of Engineering Societies. Under the able management of our energetic Publication Committee, and with the hearty co-operation of all the members, we expect the new

Journal of the Western Society of Engineers to take a front rank among current technical publications.

The Society is to be congratulated upon the increasing membership, the large number of well-attended meetings, the introduction of stereoptican illustrations of papers read, the increasing appreciation of the need of a good library and reading room, and their steady although slow development, and upon the increasing interest of the members in the work of the Society.

It is also a cause of congratulation that, without counting prepaid dues for 1896, the Society had a balance in bank January 1, 1896, of $645.58, without having asked a dollar of special subscription. After all bills for 1895 shall have been paid there will still remain about $425 to the credit of the Society.

The successes of past years should stimulate us to greater and broader efforts for "The advancement of the science of engineering and the best interests of the profession." Respectfully submitted,

CHARLES J. RONEY,
Secretary.

Chicago, January 8, 1896.

APPENDIX.

Financial Statement for 1895.

Balance on hand January 2, 1895	$ 413.92	
Receipts:		
Delinquent dues	127.50	
Resident dues for 1895	2,450.00	
Non-resident dues for 1895	738.75	
Entrance fees	220.00	
Miscellaneous receipts	109.51	
Subscription to Library Fund and sale of library duplicates	166.10	
Special fund 1894	28.00	
Interest and exchange	4.69	
Dues for 1896	10.50	
Expenditures:		
Rent, light and janitor		$ 515.87
Postage and stationery		184.41
Printing		197.05
Salaries and services		1,043.30
Journal of Association		1,411.45
Furniture and fixtures		18.40
Miscellaneous items		98.81
Library		143.60
Cash balance December 31, 1895		656.08
	$4,268.97	$4,268.97

The Finance Committee by direction of the Board of Directors has examined the Secretary's books and compared the same with the Treasurer's books, and find the foregoing account to be correct.

(Signed.) E. GERBER.
Chairman Finance Committee.

ABSTRACT OF MINUTES OF THE SOCIETY.

SPECIAL MEETING—JANUARY 23, 1896.

A Special Meeting (340th of the Society) was held at the Armour Institute, January 23, 1896, at 8 p. m., First Vice-President T. T. Johnston in the chair. Charles J. Roney, Secretary.

There were forty members and guests present.

An informal talk, illustrated by lantern views, on "Riedler Pumps" and "Riedler Compressors," was given by Mr. John Stumpf, M. W. S. E.

REGULAR MEETING—FEBRUARY 5, 1896.

The 341st meeting of the Society was held in the Society's rooms, Wednesday evening, February 5th, 1896.

The meeting was called to order by the President, with forty-one members and guests present.

The minutes of the Annual Meeting, January 7th, and of the Special Meeting at Armour Institute of Technology, January 23, 1896, were read and approved.

The Secretary, reporting for the Board of Directors, read the list of committees appointed at the meeting of the Board, held January 15, 1896, as follows:

Finance Committee: Mr. Robert W. Hunt, Chairman; Mr. L. P. Morehouse and Mr. Hiero B. Herr, members. Mr. Hunt declining appointment, Mr. E. Gerber was subsequently appointed Chairman of the Committee.

Publication Committee: The following resolution was adopted by the Board at the meeting of January 15, 1896:

"Whereas, The Publication Committee having for reasons previously stated at a regular meeting of the Society, held on November 6, 1895, been appointed to act during the present year, be it

"Resolved, That the same committee, to-wit, James J. Reynolds, Thos. T. Johnston and Charles E. Billin, are hereby reappointed, in accordance with requirements in Article III, Section 2, of the By-Laws."

Library Committee: Mr. G. A. M. Liljencrantz, Chairman; Mr. John Lundie and Mr. Frank P. Kellogg, members.

Membership Committee: Mr. Alfred Noble, Chairman; Mr. Horace E. Horton and Mr. E. Gerber, members.

At the meeting of the Board, February 4, 1896, the following applications for membership were received and placed on file and referred to the Membership Committee:

As Members—Clayton O. Billow and George Monroe Wisner, Chicago; Augustus Torrey, Detroit, Mich..

As Active Members—Gilbert H. Scribner and James S. Paterson, Chicago.

Associate—Wm. Henry Ryan, Chicago.

Mr. Nelson O. Whitney, whose resignation as a member (non-resident) of the Society was accepted December 19, 1895, having tendered a withdrawal of said resignation, the Board, by vote January 15th, re-established Mr. Whitney in membership as if he had not resigned.

The resignations of Messrs. Howard A. Coombs and Leonard S. Smith, members, to date from December 31, 1895, have been accepted by the Board.

The Secretary also reported that the President was authorized to appoint a committee of nine members for the solicitation of papers to be

laid before the Society and for publication; the committee to be selected was to reach the different lines of the profession as much as possible.

The President announced the committee as follows: Mr. John Lundie, Chairman; A. V. Powell, O. Chanute, Walter L. Stebbings, A. M. Feldman, John Ericson, John W. Cloud, E. L. Cooley, George M. Basford.

Mr. Thomas T. Johnston, of the Publication Committee, called attention to proofs of pages of the new Journal of the Society and profiles accompanying the same, and was followed by Mr. Charles E. Billin, also of the committee, in remarks regarding topical discussions and abstracts for the Journal.

The Secretary read the following report of the Committee consisting of Mr. Frank C. Hatch, Chairman; Mr. H. F. J. Porter and Mr. John Saltar, Jr., on "Standard Gauges for Thickness of Metals."

Chicago, November 15, 1895.

Members of the Society:

Your Committee, appointed to investigate and report upon the question of the use of standard gauges, for thickness of metal, etc., begs leave to report as follows: That, as this matter has been taken up and generally discussed by the American Society of Mechanical Engineers, the American Railway Master Mechanics' Association, and the several engineering societies of the country, with the result of a universal recommendation for the general adoption of the system whereby all thicknesses of wire, sheet metal, etc., be known by numbers which stand for the dimensions of the material, measured in thousandths of an inch, and for the adoption of a notch gauge of oval shape, to be marked "Decimal Gauge," in contradistinction to the circular shape ordinarily in use, your committee recommends to the members of this Society the adoption of this system of decimal gauges, and that a copy of this report be forwarded by the Secretary to the St. Louis Society, in reply to their communication on the subject.

(Signed) FRANK C. HATCH,
H. F. J. PORTER,
JOHN SALTAR, JR.

The report was received and ordered printed in the proceedings of the Society and the Committee was discharged.

Mr. Ferd. Hall called up the subject of cataloguing the Library, and after its discussion, on motion of Mr. Hall, it was voted "That the Library Committee be instructed to prepare and present at the Regular Meeting in March, a plan for the proper cataloguing of the Library by subjects or by volumes, or both; with the probable cost and the time within which this work could be completed; this work to be done within a period, say, of four months."

Mr. Liljencrantz presented the following resolution, which was adopted:

"Resolved, That a committee of three Active Members of the Society, not members of the Board of Direction, be appointed to prepare from the membership list a classified list of members, as nearly correct as may be found practicable, said list not to be printed, but to be used for the convenience of the President and the Publication Committee."

The President appointed as such committee Mr. John Ericson, Chairman; Mr. George T. Horton and Mr. Robert B. Wilcox.

On motion, it was voted that the President should appoint an Entertainment Committee for the current year, to consist of three members, not members of the Board of Direction.

The President appointed as such committee Mr. George P. Nichols, Chairman; Mr. C. E. Schauffler and Mr. T. L. Condron.

President Wallace then spoke of future work for the Society, as follows:

"I notice that the object of the Society under the new Constitution is the advancement of the science of Engineering and the best interests

of the profession. Among the means to be employed shall be meetings for the reading and discussion of papers, etc. In glancing over the notice of this meeting, I see that our Secretary makes the statement that matters of interest to the Society will be presented by me. I don't know what warrant he had for that statement beyond a remark made by me that in case there was no paper ready for any meeting, I would try to provide something to fill the vacancy. We come here with the expectation of exchanging ideas and we all wish to get the best of the bargain. We all wish to get the ideas of others without exerting ourselves—without giving ours. I necessarily plead guilty with the balance of you. It seems to me we ought all to confess our shortcomings and do what we can during the coming year to improve the reputation of our Society and ourselves, as well as the other members of the Society. There isn't anything that improves a young man so much as the preparation of a paper or entering into its discussion. There are a great many subjects that can be taken up very beneficially. Of course, being in the railroad business myself, I naturally turn in that direction first. We have before us, besides the elevation of tracks in the City of Chicago, the general problem of the elimination of grade crossings. It is a question that is coming up, not only in the different cities of the state, but also in regard to isolated highway crossings. Only a few days ago I was called upon with another engineer to examine an ordinance for the elevation of the tracks of all the railroads that pass through Joliet. No effort had been made to get the City of Joliet and the railroads to agree on any feasible plan, but the council passed a cast-iron ordinance requiring the elevation of tracks a certain number of feet, even specifying the character of the structures they were to be carried on. Among other things, I noticed that it required that the structures should be plate girders, and that there should be no supports inside of the lines of the streets. In looking over the crossings, with Mr. Clarke, we found one place where this provision would require plate girders two hundred and thirty-seven feet long. (Laughter.)

Now, the entire question of grade crossings is a matter that will bear a great deal of investigation, and there is no doubt but that if our members would take this matter up and study and agitate, as we agitated the general question of the elevation of tracks in this same Society five or six years ago, that some of us would find it to our personal advantage, and it would aid in the advancement of our Society and of our profession. There are not very many of us that have obtained employment on the elevation of tracks, but some of us have; and I think it is due to the discussion of that question brought up in this Society six or seven years ago. Of course, I feel very much interested because I have been one of the gentlemen benefited.

Even in our level prairie state of Illinois they are coming to the idea of the suppression of grade crossings. It will be only a short time until this will be a matter of great public importance. It will soon be necessary to pass laws regulating the division of expenses between the railroad corporations and the counties, states and cities having the control of the highways.

The same holds good in regard to railroad crossings. There are more grade railway crossings in the state of Illinois than there are in any other state in the country. Up to comparatively a few years ago these crossings were entirely unprotected except by the law that required all trains to come to a full stop before crossing. Of two trains coming to a crossing simultaneously, the one that whistled first was supposed to have the right to cross first. A little later the railroad companies put flagmen at the principal crossings, and then ordinary gates with signals. The railroad companies, finally realizing the delays due to crossings, and desiring to secure the right to run without stopping, secured the passage of a law in the state of Illinois which gave them the right to run over railroad crossings without stopping, provided they were protected by

interlocking plants. I presume you are all familiar with what an interlocking plant is. I can explain in a few words the essence of the principle. It is this: Where two railroad lines cross each other, signals are placed at a certain distance from the crossing; in connection with those signals is a mechanism so arranged that when the interlocking is given on one line, the danger signal is given on the other. If an engineer disregards this, his train is thrown on the ties. This is the principle of the system. It is in some cases extremely complicated, owing to numerous crossings at the same place, switches and Y tracks, distance signals, etc. These interlocking plants are becoming so complicated now that in some of the oldest plants that the speaker has been connected with, the annual cost of the operation has reached a sum of money so great that, if capitalized at four or five or even six per cent, it would pay the cost of eliminating the grade crossings.

One particular case I have in mind is the automatic interlocking plant at the crossing of the Western Indiana and Rock Island tracks, or the Western Indiana and Fort Wayne, the Alton, the Illinois Central, and the Santa Fe tracks, at Twentieth Street, where the operating expenses run up to six or seven thousand dollars a month in the severe weather in the winter time, running down to three or four thousand dollars in the summer months. This brings us to the evident necessity of eventually eliminating all grade railway crossings.

During the last three months the speaker was applied to on the part of a new company for the right to cross the Illinois Central lines at grade about one mile below Riverdale. The question of interlocking came up and was discussed, and finally the crossing company agreed to go underneath the Illinois Central tracks and the Illinois Central company agreed to raise its tracks a few feet to permit this to be done.

These are problems that it seems to me some of our members, particularly some of our members that are railway engineers, can very properly take up and discuss in papers. The subjects are new and live ones. They are subjects that would add interest to our Society meetings, attract attention from the outside public, and the discussion would be beneficial to our members.

There are a great many classes of building material that are being used in the City of Chicago and New York experimentally. We have adopted iron construction, and we incase it in terra cotta. We make our floors of tile, iron beams and concrete, and we say we have fire-proof structures. We don't fully know what the effect of fire would be on such buildings. They have never yet been tested thoroughly to determine what the effect on those buildings will be if they become hot under a severe fire when they are stored full of inflammable material and cold water is thrown on them There is quite a field for tests in regard to the action of fire and water together on our so-called fire-proof buildings. We also have no specific knowledge about the ability of the different materials that are used in the construction of these buildings to conduct heat. So far our iron buildings have been used exclusively for office buildings, but it will only be a very few years before the use of these buildings will necessarily change. We will find them piled full of dry goods and all sorts of material, which will simply add fuel to the flames. In case a fire occurs inside of them what the results will be we do not know.

Another line of investigation which it seems to me might very properly be taken up is in regard to our cements. The market to-day in Chicago is flooded with a great many kinds of cement, Portland, American-Portland and natural cements from all parts of the country. A valuable investigation could be made by a standing committee on the qualities of different cements, not to report an opinion in favor of one or against the other, but simply to report to us the relative strength of these different cements, when mixed in different proportions with sand, with different kinds of sand—fine, coarse, etc. Individual members can

make these tests when they desire to use them, but there are hardly any tests the records of which are so misleading as the tests of cement. The personal element of the person that mixes the briquettes, the temperatiure, the amount of moisture that is used, the character of the machines that is used to make the tests—there are a hundred and one things that affect the actual result of these tests that make them of very little value to an engineer unless he knows the different conditions under which the tests were made and the person who actually made the tests. I recollect in one piece of work that I had charge of where it was necessary to change the assistant who made the cements, and the character of the cement fell off 25 or 30 per cent as soon as the assistant was changed, simply due to the personal element.

Another line of investigation that seems to me to warrant a great deal of study is the uses of concrete. We have in this part of the country a dearth of first-class building stone. The stone in the vicinity of Joliet is very little used by engineers. The Illinois Central Railroad Company has extensive quarries at Kankakee. Ever since I have been connected with that company there has been more or less pressure to use that stone because it was available. We have not used it. We have even gone to the extent of using concrete for our foundation walls, for the water tables of our new buildings, in preference to using stone of that character. It has been our custom to confine the use of stone to the Anamosa stone, which we procure in Iowa, and the Bedford stone, which we procure in Indiana, neither quarry being upon the line of the Illinois Central Railroad. We are investigating the use of concrete, building our bridge abutments of it, and are now considering the use of it in the retaining walls which we contemplate building on the lake front. The question has also been considered of using it for the construction of large arches. There are several points on the road where we desire to construct arches thirty to forty feet in span. Cut stone for those arches would cost, under present conditions, twenty dollars a cubic yard. Concrete arches could be constructed for five or six dollars a cubic yard. If the concrete arches prove to be as serviceable as the cut stone arches, it would be possible for us to put in permanent work, while with stone at twenty or even fifteen dollars a cubic yard, it would be more desirable to put up an iron trestle.

Now, these are simply a few thoughts that came to me while our secretary was reading the minutes. I hope you will pardon me, if you find them crude. I have another thing here which I failed to say, which is in regard to water supply. During the last three or four years there has been a great dearth in the water supply, not only for railroads but for villages all over Missouri, Illinois and Iowa, and a great many artesian wells have been sunk, and there is a great deal of data, a great many facts that are scattered around in regard to the depths, the character of the water, the cost of sinking these wells, etc., which a little effort would collect and put into valuable shape. Even in the state of Illinois there are some very interesting facts in regard to water and the veins that contain water. I recollect two years ago our railroad was short of water in the vicinity of Pana, Illinois, and borings had been made over that country and no water obtained. One of my subordinates called my attention to the fact that there was a peculiar depression in the ground that crossed our tracks at a certain point, which depression seemed to have no reference to the natural surface drainage of the country, and he raised the point that it might have been an ancient water course that had been filled up. I authorized experiments, and, sinking a well at that place—I think we went down seventy-five or eighty feet—we developed an inexhaustible vein of water, and struck a bed of coarse gravel and sand. The theory of the young man who made the suggestion was correct.

It seems to me that there are investigations along some of the lines mentioned that might very properly be made, and I throw them out as suggestions to the Society, either for the appointment of committees to

make regular investigation along these lines, or that the individual members may be induced to make individual investigations and write us papers touching on some of these subjects. We have a large class of young members whom we never hear from. They fail to realize that they often come in contact with facts, in carrying out a piece of work which they may think may be unimportant to the older members of the profession, but which, if properly recorded and concisely stated, would prove valuable to the Society. It would also bring these young men out themselves. They would gain confidence by presenting matters of this kind before the Society, and by participating in its discussions."

Mr. Johnston called attention to the topical discussion on hydraulic cement, presented in the Journal, and on motion it was voted that a committee be appointed, the number to be at the discretion of the President, to consider the general question of cements, cement mortars and concrete.

Adjourned. CHARLES J. RONEY,
Secretary,

Note—The President has since appointed as the committee to consider the general question of cements, cement mortars and concrete, Mr. Thos. T. Johnston, Chairman, and Messrs. Alfred Noble, H. W. Parkhurst, Ernest L. Cooley and Ernest L. Ransome, members.

REGULAR MEETING—MARCH 4, 1896.

The 342d meeting of the Society was held in the Society's rooms, Wednesday evening, March 4, 1895.

President John F. Wallace in the chair and seventy-nine members and guests present.

The reading of the minutes of the previous meeting was dispensed with.

The Secretary reported for the Board of Direction, as follows: At the meeting of the Board of Direction, February 25, 1895, the following named candidates were elected to membership in the Society:

As Active Members—Robert Carter Berkeley, Jr., Henry Morton Brinckerhoff, Byron B. Carter, Samuel French Nichols. As Junior—Marion Ellis Thomas. As Associate—James O. Winston.

The following applications for membership were received, ordered filed, and referred to the Membership Committee:

As Active Member—Theodore Wilber Snow, Batavia, Ill. As Member—James Dun, Topeka, Kan.

The resignation of Mr. Seth Dean, of membership in the Society, was accepted, to date from December 31, 1895.

On March 3, 1895, the following application for membership was received, ordered filed and referred to the Membership Committee: As Active Member—Charles Frederic Foster, of Chicago.

President Wallace then read a letter from Mr. Daniel W. Mead, member of the Western Society of Engineers and member of the committee of the Illinois Society of Engineers and Surveyors, inviting the Western Society of Engineers to co-operate with the State Board of Health, the Illinois State University and the Illinois Society of Engineers and Surveyors in the appointment of a joint committee to consider and recommend sanitary legislation for the State of Illinois. Mr. Harman and Mr. Mead discussed the matter, the latter moving that the President be authorized to appoint a committee of three to co-operate in the manner suggested. Carried.

After discussion the President was authorized to appoint the committee.

The President then read the following letter from Mr. Charles J. Roney, resigning the office of Secretary:

March 2, 1896.

To the President and Board of Direction of the Western Society of Engineers:

Gentlemen—I have been informed that in the judgment of the Board

of Direction a readjustment of the duties of the Secretary is desirable in order that the increased obligations attendant on the publication of the Journal of the Society may be adequately met.

I beg therefore to tender my resignation as Secretary of the Society, that the consideration of this matter may be relieved of any embarrassment which might otherwise attend a discussion of the Society's interests. My attitude has been more fully expressed in a communication which is in the hands of Mr. T. T. Johnston. Respectfully,

(Signed.) CHARLES J. RONEY.

President Wallace announced the acceptance of Mr. Roney's resignation and the appointment of Mr. Henry Goldmark as Secretary.

President Wallace read the following letter written by him to Congressman J. Frank Aldrich, and stated that he had also sent a copy of it to each of the Presidents of the various Engineering Societies in the United States.

Chicago, February 29, 1896.

Hon. J. Frank Aldrich, M. C.,
Washington, D. C.:

My Dear Sir—House Bill No. 1470, dated December 12, 1895, and introduced by you in the first session of the Fifty-fourth Congress, which is now in the hands of the Committee on Public Grounds and Buildings, has to-day been brought to my attention as President of the Western Society of Engineers.

This Bill provides for the appointment of three architects and two officers of the United States Army, to constitute a Commission on Public Architecture; this Commission to have general control of the design and construction of public buildings. I notice this Bill also provides for the employment of special architects to design and superintend the construction of all public buildings.

The engineering questions which enter into the proper construction of large buildings are now assuming such importance that architects not only call upon engineers for assistance in the planning of buildings, but also frequently have engineers associated with them in their design and construction. The use of iron, steel and fire-proof material in the construction of buildings of late years has rendered it not only advisable, but necessary, that the assistance of the engineering profession should be utilized in attaining the highest and best scientific results in building construction. A noted cathedral is now being erected in the City of New York, and with the architect is associated one of the most prominent civil engineers in the United States. There is no question but what the best results can be obtained by the association of engineers and architects; the province of the engineer being to determine the arrangement of the skeleton construction and the nature and stability of the foundations, the architect to decorate such construction and supervise the artistic arrangement of the material. It would therefore seem eminently proper that at least one civil engineer of high scientific attainments and large practical experience should have a place on the Commission which it is proposed in this Bill to establish.

The Bill should also provide for an engineer to be associated with the architect in the supervision of the design and construction of all public buildings; and I would respectfully ask that you consider this matter, and suggest the propriety of so amending the proposed bill that the engineering profession may receive proper recognition.

Yours truly,

(Signed) JOHN F. WALLACE,
President Western Society of Engineers.

Mr. John Lundie presented the following resolution, which, after discussion, was adopted:

"Resolved, That the action of our President in endeavoring to secure

amendment to what is known as House Representatives Bill 1470 (which is now under consideration by the Fifty-fourth Congress), so that said Bill shall provide for the appointment of engineers on the Commission on Public Architecture, which it is the intention of this Bill to establish, is approved and commended by this Society; and the President is hereby authorized to appoint a committee of three to co-operate with him in an effort to obtain such amendment of this Bill as will secure the proper recognition of the engineering profession."

The President appointed as such committee, Mr. Geo. S. Morison, chairman; Mr. E. L. Corthell, Mr. Wm. Sooy Smith.

The President then read the report from the Committee on Classification of Membership appointed at the last meeting, which report on motion was received, filed and the committee discharged.

Mr. Liljencrantz read a report, as chairman of the Library Committee. After discussion by Messrs. Hall, Roney and Liljencrantz, it was moved by Mr. Cooley, and seconded, that the report of the committee commends itself to the judgment of the Society and be referred to the Board of Direction with power to act. Carried.

The following is the report:

To the President and Members of the Western Society of Engineers:

Gentlemen—At the regular meeting of this Society, held on the 5th of February, 1896, the following resolution was offered by Mr. F. Hall and passed, viz.:

"That the Library Committee be instructed to prepare and present at the regular meeting in March, a plan for the proper cataloguing of the Library, by subjects or by volumes, or both, with the probable cost and the time within which this work could be completed, this work to be done within a period, say, of four months."

In pursuance of this resolution the Committee begs leave to submit the following

REPORT.

The resolution calls for suggestions or information on the following points, viz.:

1. A plan for cataloguing the Library.
2. The probable cost of this work, and
3. The time for completing the same.

Before submitting a plan for cataloguing the Library, it will be necessary to state briefly the chief object in view and what has been done to date for this purpose.

As understood by the Committee, the chief object sought is to prepare, in the shortest space of time practicable, a catalogue, which will enable members to find any desired volume with the least possible trouble or waste of time, rather than an elaborate index, which would take an indefinite period to complete.

There are at present two different kinds of Catalogues of the Library: First, the so-called "Accession Book"; second, the "Card Index."

The former is valuable as an inventory of the Library, as it gives the titles of the volumes it contains, in approximate order as received, up to about two years ago, with columns—partly filled—for a variety of information concerning each volume, such as: "Number of pages," "Style of binding," and so forth, but without any reference to its location in the Library. Therefore, for the purpose of finding a book it is, in its present condition, of no value whatever.

The "Card List" is arranged alphabetically according to authors. Provision is here made for indicating, eventually, a book's position in the Library. If this is done, a volume may be traced by the aid of the card list, provided the name of the author is known. It is the opinion of the Committee, however, that in order to make the card list more gener-

ally useful, it should be re-arranged, as nearly as may be found practicable, according to the subjects or topics, as all that has been written on any particular "subject"—whether by authors known or unknown—is generally of more importance than what one particular author may have written on a variety of subjects.

It is of course impossible to make a correct and complete index of all the topics embodied in the various books, journals, pamphlets, etc., in the Library, within a reasonable time and at a cost within the limits of the Society's means. An approximation is all that can be accomplished. On this basis the Committee proposes the following

PLAN FOR CATALOGUING:

All books, pamphlets, etc., should first be divided into two classes; one containing volumes treating more or less exclusively of some special subject or branch of engineering, the other, all volumes of miscellaneous contents. The former class should then be arranged in divisions according to their various subjects or topics*, placed in alphabetical order according to their Titles and marked, with a suitable sign or mark, indicating its position in the library, as for example: "D b 12," which would indicate that the book belongs in the book-case marked "D," on the shelf "b" (the second from the top), and the twelfth in order from the left on the shelf.

The second class should be arranged in a similar manner—alphabetically according to Title—but would come under the heading of: "Works Containing Mixed Topics."

When this is completed any volume may be found. Afterwards the indexing according to subjects may be indefinitely extended, as available time and funds will permit.

Some plan may be found practicable later on, by which the work of extracting and classifying valuable items from current literature can be distributed between a number of different Committees, appointed for that purpose.

Some works, such as: "The Proceedings of the Institution of Civil Engineers," "The Reports of the Chief of Engineers, United States Army," and others, have special volumes containing complete and conveniently arranged subject indexes, and it is proposed to place all such "Subject Indexes" in a conspicuous place in the Library.

2. THE PROBABLE COST.

Before commencing the cataloguing, it will be necessary to have some preliminary work done. Shelving should be placed along the windows in the large room, to hold all periodicals of the current year, and in the small room, to provide places for books received but not yet catalogued, for volumes ready for binding, for duplicates, etc. Bids have been received for this work. The shelving can be made for not exceeding $87. An additional table will be required. This is estimated at $20. The cost of labor in arranging the Library as suggested above is estimated at from $200 to $250; or a total approximate cost of $330 to make the Library useful to the Members in a reasonably short time.

3. TIME FOR COMPLETION.

The work of cataloguing can never be considered as actually completed. It will necessarily be continuous. It can be put in such shape, by or before June next, that volumes now on hand may be found without much difficulty.

The committee desires to recommend in this connection, although not called for in Mr. Hall's resolution, that the small room be so arranged

*In harmony with the list of Topics prepared by the "Committee of Nine."

that it may be used for meetings of the Board of Directors, or of committees, as discussions and deliberations can be carried on there free from all disturbances.

G. A. M. LILJENCRANTZ, Chairman,
FRANK P. KELLOGG,
JOHN LUNDIE.

Mr. Reynolds, for the Publication Committee, reported orally on the steps necessary to obtain admission to second-class postal rates for the Journal. After discussion a proposition to amend Article VI, Section III of the By-Laws so as to reduce all dues by $2, was presented by Messrs. Chas. E. Billin, T. L. Condron and J. J. Reynolds for adoption.

The Secretary then read a paper by Mr. Wm. G. Potter on the "Relative Cost of Rock Excavation by use of the Several Devices in Operation on the Chicago Drainage Canal." Mr. T. T. Johnston stated on behalf of Mr. Randolph that the matter was compiled by Mr. Potter from the records of the Sanitary District with his permission, and that he regarded the paper as a very creditable one.

The Secretary then read a memoir of Mr. Willard S. Pope, late member of the Society. After a few remarks, Mr. Onward Bates moved that the memoir be printed in the Society's Journal and a copy sent to Mrs. Pope. Carried.

President Wallace then proposed that the Society go into executive session before reading a letter addressed to the President, the contents of which were such that the Society might or might not desire publicity to be given them beyond the members of the Society, and it was so voted.

The Society then went into executive session, after which it adjourned.

CHARLES J. RONEY,
Secretary.

REGULAR MEETING—APRIL 1, 1896.

A Regular Meeting (the 343d of the Society) was held in the Society's rooms, April 1, 1896, at 8 p. m., First Vice-President T. T. Johnston in the Chair. Henry Goldmark, Secretary.

There were forty-six members and guests present.

The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction as follows:

At a meeting of the Board, held March 17, 1896, the following-named persons were declared elected to membership in the Society:

As Active Members—Geo. M. Wisner, Clayton O. Billow, James Dun, Augustus Torrey, Theo. W. Snow, John Waterbury Crissey.

As Associates—Wm. Henry Ryan, Gilbert H. Scribner, Jr., James S. Paterson.

Applications for membership were received from the following:

Charles Frederick Dose, Julian Switzer Hull.

The Secretary then made the following statement:

The Secretary would like to make an explanation with regard to the paragraph in the minutes of the last meeting referring to a proposed amendment of Article VI, Section 3, of the By-Laws. The object of this amendment was to secure the admission of our Journal to second-class postal rates, without extra expense to the members. Since the last meeting Mr. J. J. Reynolds, a member of the Publication Committee, went to Washington and secured the admission of the Journal as second-class matter, so that the proposed amendment became unnecessary. One of the original proposers, Mr. C. E. Billin, therefore withdrew his signature, and the ballot was not sent out.

The following remarks were then made by Mr. G. A. M. Liljencrantz:

I have been requested by a past member of the Society, a gentleman well known in this city, Mr. S. S. Greeley, to present a petition for signatures by those who are in favor of the adoption of the metric system. It

is accompanied by House Bill 7251, and if the Chair will so rule, I will bring it up for the Secretary to read.

The Secretary then read the following communication:

American Meteorological Society,
Office of Secretary,
Columbia University, 49th Street and Madison Avenue.
New York, March 15, 1896.

Dear Sir: You are aware, no doubt, that the Committee on Coinage, Weights and Measures, of the House of Representatives, Hon. C. W. Stone, Chairman, has directed that a favorable report be made to the House of a bill making the use of the metric system obligatory in the United States after certain dates named in the bill. The bill reported is a substitute for the Hon. D. M. Hurley's bill. A copy of the substitute bill is enclosed.

It is very important that all interested in this bill should act promptly and vigorously.

If you are in favor of the bill sign the enclosed petition and obtain on it the signatures of friends in your neighborhood. Mail the signed petition, with a personal letter, as soon as practicable, to your Representatives in Washington, D. C. Kindly send the Society a postal card stating when you sent the petition and the number of names signed.

The Society would be glad to know the condition of feeling toward the metric system in your vicinity.

Yours respectfully,

B. A. GOULD, President.
J. K. REES, Secretary.

FIFTY-FOURTH CONGRESS, FIRST SESSION—H. R. 7251.

(Report No. 795.)

IN THE HOUSE OF REPRESENTATIVES.

March 16, 1896.

MR. CHARLES W. STONE, from the Committee on Coinage, Weights and Measures, reported the following bill in lieu of H. R. 2758; which was referred to the House Calendar and ordered to be printed.

A BILL

To fix the standard of weights and measures by the adoption of the metric system of weights and measures.

Be it Enacted by the Senate and House of Representatives of the United States of America in Congress Assembled, That from and after the first day of July, eighteen hundred and ninety-eight, all the Departments of the Government of the United States, in transaction of all business requiring the use of weight and measurement, except in completing the survey of the public lands, shall employ and use only the weights and measures of the metric system.

Sec. 2. That from and after the first day of January, nineteen hundred and one, the metric system of weights and measures shall be the only legal system of weights and measures recognized in the United States.

Sec. 3. That the metric system of weights and measures herein referred to is that in which the ultimate standard of mass or weight is the international kilogram of the International Bureau of Weights and Measures, established in accordance with the convention of May 20th, eighteen hundred and seventy-five, and the ultimate standard of length is the international meter of the same bureau, the national prototypes of which are

kilogram numbered twenty and meter numbered twenty-seven, preserved in the archives of the office of standard weights and measures.

Sec. 4. That the tables in the schedules annexed to the bill authorizing the use of the metric system of weights and measures passed July twenty-eighth, eighteen hundred and sixty-six, shall be the tables of equivalents which may be lawfully used for computing, determining, and expressing the customary weights and measures in the weights and measures of the metric system."

Mr. Liljencrantz—Mr. Greeley desired me to request the members present at the meeting, who are interested in the subject, to please affix their signatures to the petition which I will leave with the Secretary, after the close of the meeting; and I would like very much to make the motion that a certain day be set aside for the discussion of this very important subject. Mr. Greeley has taken a great deal of interest in the subject, and a number of years back read a paper before the Society stating the disadvantages of the present system and the great desirability of adopting the new and desirable system. I would like to make that motion, Mr. Chairman. Seconded by Mr. Lundie. Carried.

The Chair—The Secretary has a letter which was submitted to the Board of Direction at one of its recent meetings, and the Board of Direction desired the letter to be read before the Society.

The Secretary then read the following letter from Mr. H. B. Seely:

Chicago, Ill., March 14, 1896.

Western Society of Engineers,
1737 Monadnock Block, City:

Gentlemen—Some days ago I received a letter from a former client who was greatly alarmed about the possible condition of his fire-proof building, of tile construction, having read some wild statements of reporters in the New York papers with reference to the rusting of iron. I reassured him on the subject, but it has occurred to me that the tearing down of the old postoffice in this city will afford an excellent chance to determine what portions, if any, of fire-proof buildings are liable, to a dangerous degree, of deterioration through the process of rusting. The construction of the Government building floors comprises a corrugated iron arch with concrete and a metallic ceiling, affording a chance to examine the action of confined air spaces on metals. It seems to me that an examination of the building as it is being torn down, by an expert committee appointed by your Society, possibly with representatives from the Architectural Association, would be of great value and set at rest some misapprehensions in the public mind that are more or less detrimental to the progress of fire-proof construction.

Very truly yours,

H. B. SEELY.

Mr. T. L. Condron—I had a talk with Mr. Seely, who, as the members know, is an architect. He told me that he was going to send this letter to the Society, and also that he thought the iron work in the post-office building would afford an ample opportunity for study. It seems that, although the postoffice was built some twenty years ago, there was an unusual amount of iron used in its construction; there being I beams used in it at the time when beams were sold at 10 cents a pound. I think that an investigation would certainly prove of value, if there is a considerable amount of iron work in that building, and I would therefore make a motion that a committee be appointed by the Western Society of Engineers, to act in co-opera ion with a similar committee of the Architects' Chapter here, to make an ficial report upon the state of the iron work that is found in that builuing. It seems to me that two members of this Society, acting with two members of their Society, would form an amply large committee for such work, such committee to be appointed by the Chairman.

Mr. J. C. Bley moved, as an amendment, that a committee be appointed to investigate the Government building and to invite the co-operation of any committee that may be appointed by a similar organization.

The foregoing amendment was accepted by Mr. Condron; the motion as amended was then put to vote and carried.

A paper was then read by Mr. Keating, entitled: "Coefficients in Hydraulic Formulae Determined by Measurements of Flow in the Desplaines River Diversion Made by the Sanitary District of Chicago."

This paper, with the discussion that followed, will appear in the April number of the Journal.

The topical discussion on "Cements, Mortars and Concretes" was then taken up, a paper on the subject by Major W. L. Marshall, Engineer Corps, U. S. A., being read, and followed by discussion. All of this matter is printed in the April number of the Journal.

LIST OF PERIODICALS ON FILE IN THE

Library of the Western Society of Engineers,

1737 Monadnock, CHICAGO, ILL.

April 15th, 1896.

DOMESTIC PUBLICATIONS.

NAMES OF PUBLICATION.	PERIODS	PUBLISHED A
Age of Steel	Weekly	St. Louis
American Architect and Bldg. News.	"	Boston
American Bulletin (I. & S. Ass.)	"	Philadelphia
American Contractor	"	Chicago
American Engineer	Monthly	N. Y.
American Miller	"	Chicago
Architecture and Building	Weekly	N. Y. & Chic.
Brick	Monthly	Chicago
Brick Builder	"	Boston
California Architect	"	San Franci'co
Chicago Journal of Commerce	Weekly	Chicago
Clay Worker	Monthly	Indianapolis
Colliery Engineer	Weekly	Scranton, Pa.
Electrical Age	Weekly	N. Y.
Electrical Engineer	"	N. Y.
Electrical Industries	Monthly	Chicago
Electrical Journal	Semi-Mont'ly	Chicago
Electrical Review	Weekly	N. Y.
Electrical World	"	N. Y.
Electricity	"	N. Y.
Electric Railway Gazette	"	N. Y.
Engineer, The	"	N. Y.
Engineer and Contractor	"	San Franci'co
Engineering and Mining Journal	"	N. Y.
Engineering Mechanics	Monthly	Philadelphia
Engineering News	Weekly	N. Y.
Engineering Record	"	N. Y.
Heating and Ventilation	Monthly	Chicago
Home Study	Weekly	Scranton
Industrial World	"	Chicago
Inventive Age	Monthly	Washington
Iron Age	Weekly	N. Y.
Iron Trade Review	"	Cleveland
L. A. W. Bulletin	"	Boston
Machinery	Monthly	N. Y.
M. A. C. Record	Weekly	Lansing, Mich
Manufacturers Record	"	Baltimore
Marine Journal	"	N. Y.
Marine Review	"	Cleveland

NAMES OF PUBLICATION.	PERIODS	PUBLISHED AT
Master Steam Fitter................	Monthly	Chicago
Metal Worker......................	Weekly	N. Y.
Mine and Quarry..................	Monthly	Chicago
Mining and Scientific Press.........	Weekly	San Franci'co
Mining Industry...................	"	Denver
Municipality and Country	Monthly	Buffalo
Open Court........................	Weekly	Chicago
Popular Science News.............	Monthly	N. Y.
Power.............................	"	N. Y.
Progressive Age..................	Semi-Mont'ly	N. Y.
Public Opinion....................	Weekly	N. Y.
Railroad Car Journal..............	Monthly	N. Y.
Railroad Gazette..................	Weekly	N. Y.
Railway Age.......................	Weekly	Chicago
Railway Master Mechanic...........	Monthly	Chicago
Railway Review...................	Weekly	Chicago
Roadmaster and Foreman..........	Monthly	Chicago
Roller Mill........................	"	Buffalo
Rose Technic......................	Monthly	Terre Haute
Safety Valve......................	"	N. Y.
Scientific American............. ...	Weekly	N. Y.
Scientific Machinist...............	Semi-Mont'ly	Cleveland
Spanish American Industrial Journal	Monthly	San Ant., Tex.
Spokesman........................	"	Cincinnati
Stationary Engineer...............	"	Chicago
Street Railway Journal............	Monthly	N. Y.
Street Railway Review............	"	Chicago
Technical Journal.................	"	N. Y.
Tin and Terne and Metal Worker...	Weekly	Pittsburg
Tradesman, The...................	"	Chattanooga
Water and Gas Review............	Monthly	N. Y.
Western Electrician...............	Weekly	Chicago

FOREIGN PUBLICATIONS.

NAMES OF PUBLICATION.	PERIODS	PUBLISHED AT
Canadian Engineer.................	Monthly	Toronto
Colliery Guardian	Weekly	London
Electrical Engineer................	"	London
Electrical Industries............ ...	Monthly	London
Electricity.........................	Weekly	London
Electro Technisher Anzeiger.......	Semi-Weekly	Berlin
Engineer, The.....................	Weekly	London
Engineering.......................	"	London
Engineering Review...............	"	London
Indian Textile Journal.............	Monthly	Bombay
Industrial Canada.............	"	Toronto
Industries and Iron................	Weekly	London

NAMES OF PUBLICATION.	PERIODS	PUBLISHED AT
Invention	Weekly	London
Iron and Steel Trades Journal	"	London
L'Industrie Electrique	Semi-Mont'ly	Paris
Lightning	Weekly	London
Mechanical World	"	London
Mining Review.	Monthly	Montreal
Mining World	Weekly	London
Plumber and Decorator	Monthly	London
Practical Engineer	Weekly	London
Railway World	Monthly	London
Revue General des Science	Semi-Mont'ly	Paris
Revue Technique	Bi-Monthly	Paris
Tecknick Tidskrift	Weekly	Stockholm
Zeitschrift, Dampfkessel	Semi-Mont'ly	Breslau

PERIODICALS.

NAMES OF PUBLICATION.	PERIODS	PUBLISHED AT
Agricultural College, Colorado		Fort Collins
American Geologist	Monthly	Minneapolis
American Journal of Science	"	New Haven, Conn.
American Magazine of Civics	"	N. Y.
American Meteorological Journal	"	Boston
Arena	Monthly	N. Y.
Boiler Maker	Monthly	Chicago
Boston Society of Civil Engineers		Boston
Cassier's Magazine	Weekly	N. Y.
Colorada Scientific Society		Denver
Compressed Air	Semi-Mont'ly	Chicago
Construction News	Weekly	Chicago
Electrical Engineering	Monthly	Chicago
Engine and Boiler Room	Monthly	Chicago
Engineers' Club of Philadelphia		Philadelphia
Engineers' Club, St. Louis—Bulletin		St. Louis
Engineering Association of the South		Nashville
Engineering Club, Cincinnati		Cincinnati
Engineering Society of Western N. Y.	Bi-Monthly	Buffalo
Engineering Society of Western Pa.	Monthly	Allegheny
Engineering Magazine	"	N. Y.
Gunton's Magazine	"	N. Y.
Hardwood	Semi-Mont'ly	Chicago
Irrigation Age	Monthly	Chicago
Journal Association Eng. Societies	"	Philadelphia
Journal Franklin Institute	"	Philadelphia
Journal Mass. Highway Association	Quarterly	Boston
Journal N. E. Water Works Ass'n	Monthly	New London
Journal of the U. S. Artillery		Fort Monroe
Lehigh University—Papers		S. Bethlehem

NAMES OF PUBLICATION.	PERIODS	PUBLISHED AT
Milling	Weekly	Chicago
Mining	Monthly	Spokane
Monist	"	Chicago
Montana College—Catalogue		Bozeman
N. Y. Yacht Club		N. Y.
North-West Ry. Club	Monthly	St. Paul
Notes and Queries	"	Manchester
Pratt Institute Monthly	Monthly	Brooklyn
Rose Polytechnic Institute—Bulletin.		Terre Haute
Searcher	Monthly	Philadelphia
Stevens' Indicator	"	Hoboken,N.Y
Stone	"	Chicago
Technology Quarterly	Quarterly	Boston
Trustees Sanitary Dist.—Proceedings		Chicago
University of Wisconsin—Bulletin		Madison
Western Railway Club	Monthly	Chicago

FOREIGN.

Archiv für Eisenbahnwesen	Bi-Monthly	Berlin
Societe Industrielle—Bulletin	Monthly	Mullhouse

LITERARY NOTES.

The committee wishes to return thanks for donations to the Library. The receipt of old numbers, Periodicals or Magazines, is acknowledged because they sometimes complete our files, and enable us to bind a volume for our shelves.

Since the 1st of Jan., 1896, we have received gifts as follows, from the donors named:

Mr. W. T. Casgrain, 5 vols. Engineering Record.
6 vols. The American Engineer, 2 vols. American Agriculturist.
4 vols. Geology of Wisconsin, with the Atlas, 1873–1879.
4 vols. Geol. Survey of Michigan, with the Atlas, 1869–1873.
1 vol. 5, U. S. Geological Survey, Monograph, 1883.
1 Dictionaire de Marine, Paris, N. D.
1 Prof. Papers, U. S. E. C., No. 16, Gillmore, 1868.
1 " " " No. 22, N. Sea Canal, 1872.
1 Report U. S. Coast Survey, 1860.
1 Isthmus of Tehanutepec, Shufeldt.
1 Report Chief Engineer, U. S.—The Atlas for, 1892.
2 Reports Coast Survey U. S., 1867–1868.
1 War Dep't Report, Prelim., Nevada and Arizona, 1871.
1 Annual, 17th Dep't Public Works, Chicago, 1892.
1 Gilespies' Land Surveying, 1872.
16 Valuable Pamphlets on Canals and Tunnels, various.
2 Large Atlases.
Mr. John Saltar, Jr., 278 Periodicals—Various, 1894–1895.
Mr. W. A. Remington, 203 " " 1893–1896.
Mr. E. Gerber, 10 " " 1893–1895.
Mr. J. R. Cravath, 1133 " " 1894–1895.
32 Patent Office Publications; 5 Jour. Franklin Inst., 1894–1895
Mr. H. P. Boardman, 2 Engineering News, 1894.
Mr. F. De Land, 6 Electrical Engineering (to complete), 1894–1895
26 Periodicals—Various, 1894–1895.

Thanks are also due to several members who have assisted in arranging books and periodicals.

Our reading room is open to visitors now until 5:30 p. m. on week days—except Saturdays until 3 p. m., and members should avail themselves of the feast from some of the 160 periodicals we have elsewhere herein listed, and which we did not have on file before the society published its own Journal.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

VOL. I. JUNE, 1896. No. 3.

VII.

DATA PERTAINING TO RAINFALL AND STREAM FLOW.

By THOMAS T. JOHNSTON, Mem. W. S. C. E.

Much investigation has been made of the relation between the maximum rainfall on a catchment basin and the maximum rate of flow therefrom. The term "catchment basin" means the whole area whose surface drains to a given point in a river or stream. So it happens that the several catchment basin formulae have been derived, the more important of which, copied from various authorities, may be symbolized briefly as follows:

Q—function of A, s, l, w, p, r, C

in which—

Q—maximum rate of flow, usually stated in cubic feet per second.

A—area of catchment basin, stated variously as square miles, acres or other units.

s—general declivity of surface of the basin, stated as the fall in feet per foot of distance. This is evidently a very general quantity apt to be differently estimated by different individuals, though perhaps the best that can be done.

l—general length of the basin in miles or other units.

w—general width of the basin in miles or other units.

p—equal some quantity depending on the nature of the surface drained, whether it be absorptive soil or paved surface or some other kind of surface.

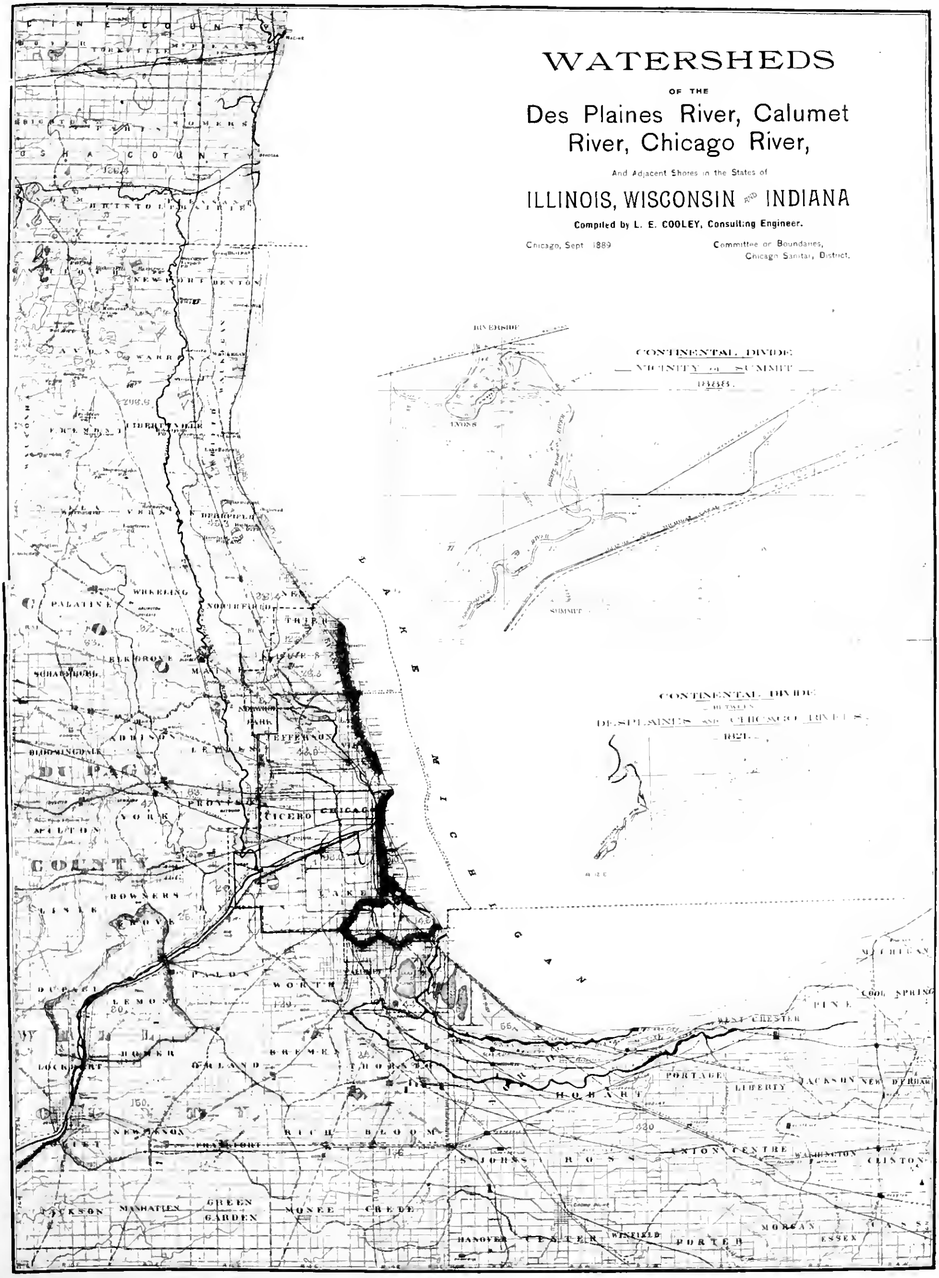
r—rainfall measured in inches per unit of time.

C—a quantity, the value of which depends on every thing else not considered in the other quantities entering the equation.

The equation is necessarily a generalization of the broadest kind and it is no wonder that the various authorities have given it widely differing forms, involving various powers and roots and logarithms of the variables, and no wonder that the several forms,

when applied to one and the same case, give widely differing results as to maximum flow. A striking illustration of this state of affairs is found in an application of the formulae to a determination of the flow from the Desplaines river basin, made by the writer nearly ten years since, when in the service of the Chicago Drainage and Water Supply Commission. The subject was reported upon at the time and the report forms appendix hereto.

The purpose in hand may be best stated by making reference to the map, figure 89, and being of peculiar interest in connection with the construction of the Chicago Drainage Canal, the story will be told in some detail. The boundaries of the Desplaines river basin will first be noted, and next the location of the Chicago drainage canal. It was thought that the flood waters of the river might prove to be a serious obstacle to the construction of the canal, which was at the time being considered by the commission, and therefore, that if the river could be diverted, this menace could be removed. Furthermore, and more important, it will be noted that at a point just south of Riverside (see map) the flood waters of the river divided, the one part going to Lake Michigan and the other part to Joliet, and thence to the Mississippi river. Estimates for the drainage canal had contemplated that the canal should have a capacity for the flood flow from the Chicago river basins only (see map), and therefore, unless its capacity be overtaxed, that part of the Desplaines floods flowing east must be diverted and disposed of otherwise. To dispose of all of the floods of that river to and through Joliet was thought to be a doubtful project, because floods to the south of Joliet would be increased and it was doubtful if the necessary legislation for such disposition could be obtained. Therefore disposition of the waters, or at least a part of them, elsewhere was desirable. Finding Park Ridge on the map, a line may be drawn east to the north branch of the Chicago river, from which place the north branch may be followed northerly or southerly. Going to the south when Bowmanville is reached, a line may be drawn east to Lake Michigan. A channel from Park Ridge to the lake on this route was styled the Bowmanville cut-off. Proceeding northerly on the north branch to a point west of Winnetka, and thence directly to the lake and the Skokie cut-off will have been traversed from Park Ridge. By way of one or the other of these cut-offs it was designed to divert to Lake Michigan all of the waters draining to Park Ridge, a dam of moderate height, and not causing much flowage of land to be constructed just below this point to assist to the desired end. It was contemplated also that the upper waters of Salt Creek (see map) could be diverted to the Desplaines at Park Ridge and thence to the lake, a proper channel being excavated across the flat intervening country. It was desirable to know, as closely as practicable, the flow that might be expected at Park Ridge, and, the diversion at that point having been effected, the flow that would occur at Joliet from that part of the Desplaines basin not diverted, it being understood that flow toward Chicago below Riverside was entirely



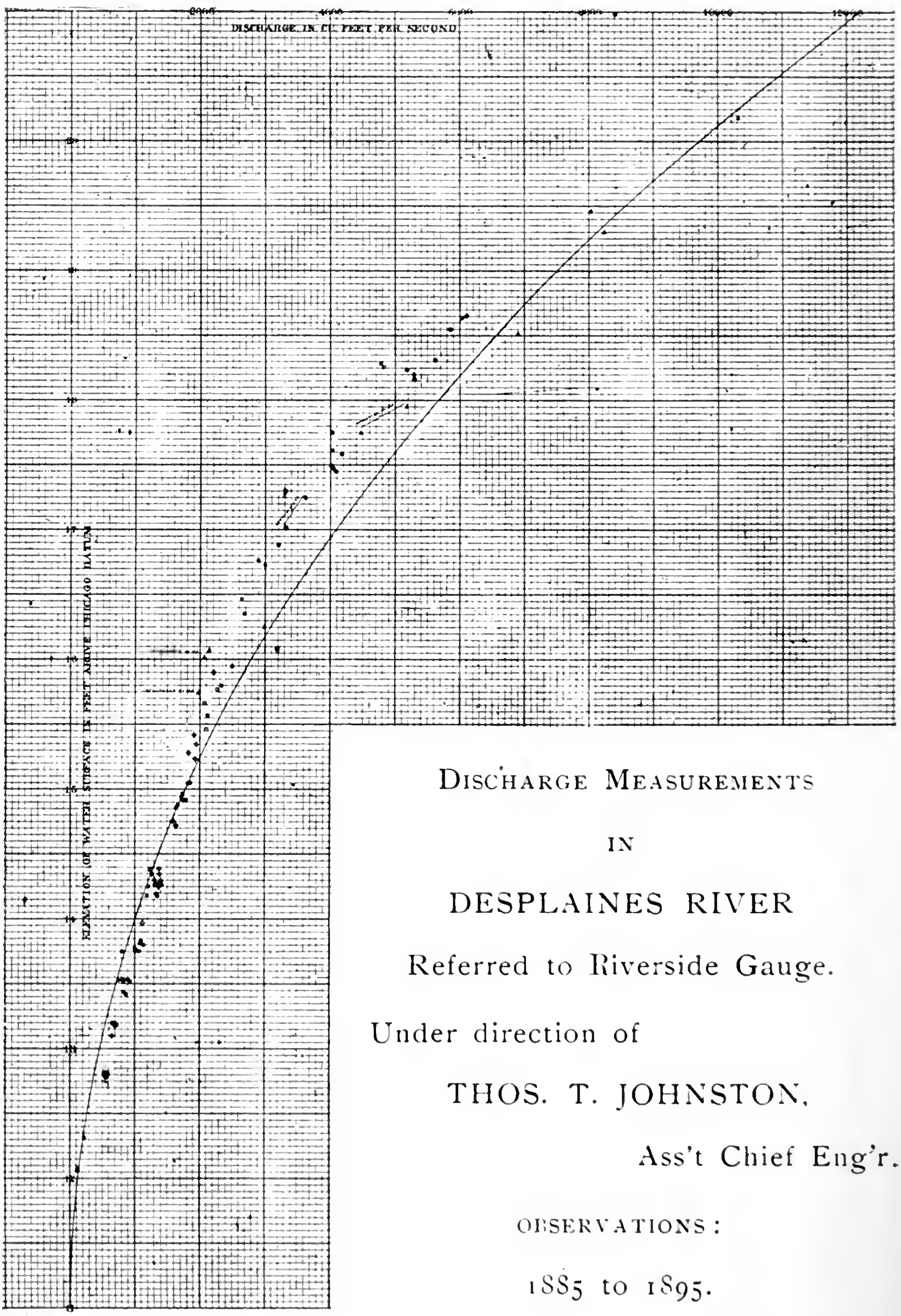
DONOHUE & HENNEBERRY, PRINTERS, ENGRAVERS AND BINDERS. CHICAGO.

prevented. These things could not be determined by direct measurement, and even if they could there was not time to wait for floods which could be measured. Consequently resort was necessary to catchment basin formulae, and the calculations were accordingly made, as shown in the copy of the report appended. It is sufficient here to state the results for maximum flow that might be expected to pass Riverside:

NAME OF FORMULA.	Maximum flow in cubic feet per second.
Dickens	104.110
Dredge	53.693
Fanning	43.205
Burkli-Ziegler	700
Craig	12,120
O'Connell	13,620
Cooley	13,250

That some of the results were entirely erroneous is evident, but the layman would be bothered to determine which they were. Those familiar with the flow in streams could eliminate the most erroneous at a glance. A happy circumstance enabled even a closer determination by an engineer, as follows: In the winter of 1886-1887 a flood occurred in the Desplaines, the magnitude of which was measured at Riverside by the writer. The flow was determined at different stages of the river, thus enabling the construction of the discharge curve at Riverside. Subsequently many other measurements were made to the same end. The curve is shown on Figure 90, by which it may be seen that the flow at any stage of the river may be estimated quite closely, if the stage be known. The measurements of 1886-87 were, however, numerous enough to determine the curve quite closely. The extreme high water of the river having been discovered in a search for high water marks, the curve enabled the determination of the maximum discharge of the river. This being known, it was compared with the results of the computations from the formulae. Now, the parts of the Desplaines basin are quite similar one to another, and to the whole basin, and the formula thus selected was considered the best adapted for application to the several parts of the basin, the maximum flow from which could not be determined by direct measurement.

It requires but little consideration to conclude that the hydraulics of the Desplaines basin is and has been of much concern in relation to the Chicago Drainage Canal, and will be of much importance in relation to the drainage to which it must be subjected as it becomes more densely populated. The particular point of present importance is to learn the value of as detailed a knowledge of the hydraulics of the basin as practicable, and to understand how little real value can be attached to catchment basin formulae unless their use is supported by a familiarity with the various causes which influ-



DISCHARGE MEASUREMENTS

IN

DESPLAINES RIVER

Referred to Riverside Gauge.

Under direction of

THOS. T. JOHNSTON,

Ass't Chief Eng'r.

OBSERVATIONS:

1885 to 1895.

Fig. 90.

ence and modify the flow from the basin. With this thought in view, the Chicago Drainage and Water Supply Commission, the City of Chicago and the Sanitary District of Chicago have maintained a gauge at Riverside almost continuously since early in 1886, the stage of the river being recorded once or more each day. The gauge readings thus recorded, together with the discharge curve, are the data by which the volume of water daily passing Riverside has been determined, and also the flow each week, or month, or year. The weather authorities of the United States and the State of Illinois have recorded the rainfall during the period in question at a number of stations in and near the river basin, thus enabling a close approximation to the rainfall in the basin. These data, taken all together, enable a study of the relation of rainfall to the stream flow at Riverside, the area of basin involved being about 630 square miles. The map, Figure 91, shows the outline of the basin and adjacent country. Figure 90 is the discharge curve at Riverside, above described. Table XXXI is a statement of the stage of the river each day, the flow each day, the flow each month, the rainfall at certain stations each month, and the proportion of stream flow to total water falling in the basin each month, estimated on basis of Chicago rainfall being uniform over the whole basin. Table XXXII is largely a condensed statement of most of the data in Table XXXI. It shows the proportion of stream flow to rainfall each month and each year through which the data are continuous. The use of the Chicago rainfall as measuring the rainfall over the whole basin is nearly, if not quite correct, when periods of time are considered, the duration of which is as much as a month, or a year. Should it be desired to examine the state of affairs in periods not longer than one week then the rainfall at a number of stations in the basin should be examined. This will be done in one case to be described below. However, the data for all available stations in the basin are given for each month, thus enabling a more detailed examination if desired. The daily rainfall at any of the stations can be had on application to United States Weather Bureau in Chicago. Table XXXI is presented to make a public record of the data and to afford a basis for more detailed study. Table XXXII contains some results to which it seems worth while to draw direct attention.

It is interesting to note that, since the establishment of the weather office at Chicago in 1871 the maximum rainfall in twelve consecutive months occurred between September 1881, and September, 1882, and the minimum rainfall for a similar period occurred between November, 1894, and November 1895. The former was 53.43 inches, and the latter 22.86 inches. The latter period only is covered by the records herewith, and it is interesting to note the small proportion of rainfall which passed Riverside. The total falling was 22.86 inches, and the total flowing off was equivalent to 1.39 inches, or but 6.1 per cent of the total falling. The average annual rainfall at Chicago is between 35 and 36 inches, based on records covering the past twenty-five years. The rainfall of 1892 was

nearly this amount, and the proportion of rainfall running off was a much larger percentage. It is highly probable that in the year of maximum annual rainfall the proportion was still larger, possibly more than 50 per cent. The small proportion running off in the year of minimum rainfall is instructive in its bearing on the quantity of water that may be collected for storage from basins or parts of basins similar to that of the Desplaines. It appears that a wide range exists in the proportion of annual rainfall that may be expected to flow off, the cause of which is the wide variation of rainfall one year with another, the concentration of rainfall and other things, some of which will appear in the following.

The proportion flowing off during the winter months is in striking contrast to that flowing off during summer months. Thus, in May and June, 1892, the rainfall was, in the aggregate, 17.38 inches. Table XXXI shows that the flow off due to these rains terminated early in July, and amounted to 10.28 inches, or 59 per cent. of the total. Again, in September, 1894, with the extraordinary rainfall of 8.28 inches, the quantity running off is nearly nothing. Now take the months December to March inclusive, in the winter of 1892 and 1893, the total rainfall was 7.84 inches, and the quantity flowing off was 5.51 inches or 70 per cent. of the total falling. Again, take the months December to April, inclusive, in 1886 and 1887, the rainfall was 11.34 inches, and the quantity flowing off was 9.64 inches, or 85 per cent. of the total. These facts are instructive as indicating that any scheme for storage of water in such a basin must be based mainly on collecting winter rainfall, for in the summer there may be frequently six or more months when little or no water can be collected; likewise, if the question be one of feeding a canal. In this climate, when the ground has frozen in the early winter, it generally remains in that condition until the thaw of the following March or April. During this period little or no water is absorbed by the soil and none taken up by vegetation. Thus it is that 70 to 90 per cent. of the rainfall during that period flows off in the streams, the remainder being lost in evaporation. On the contrary, the soil being open in the summer, much of the rainfall is absorbed at all times, and after a prolonged period of dry weather even a phenomenal rainfall, like that of September, 1894, nearly all of which fell in the course of a week, may be entirely absorbed. This rainfall amounted to about seven (7) inches over the whole basin in one week, the maximum rainfall in twenty-four hours at Chicago being 2.95 inches. A small part of this rainfall on frozen ground, already more or less covered with snow and ice, would cause a flood. Here again is some instruction, as follows: It must be remembered that systematic records of the weather have been in existence at Chicago but twenty-five years, and the records of floods and high water elevations, except by tradition, a much shorter period. The highest authentic water marks in the Desplaines are those of 1881 and 1892, and indicate a maximum flow of 13,500 cubic feet per second. The former a winter flood and the latter a

summer flood. Now it is known that in the early part of 1849 a winter flood occurred which had the effect of cleaning all the bridges and shipping from the Chicago river, but there is no record either of rainfall or flood height, except that the latter was phenomenal. Not since Chicago has become a great city has anything of the kind happened and there can be no denying that it may occur any winter. If the damage done in 1849 can be made any measure of what would result at this time, there is no measuring the money loss that would be involved, to say nothing of loss of life. Now as to the chance of the recurrence of a flood such as that of 1849 probably was. Should a winter rainfall occur, say in February or March, such as occurred in the week above cited, in September, 1894, seven inches of rainfall, then a great flood would result. This conclusion is supported by the comparison of the flood of February, 1887, with the rainfall at that time. The flood culminated after a rainfall of less than two inches. That heavy rainfalls occur in winter is shown by the records for December, 1895, when 5.92 inches fell in the course of a week just preceding Christmas. The prospect is not pleasant to contemplate, or rather it would not be if it were not for certain works constructed in connection with the Chicago Drainage Canal, for the city and Chicago river have been developed with little or no regard to a contingency of the kind in question, and it has been due more to luck than science that a flood disaster, similar to that of 1849, has not resulted. There is no school like experience, and doubtless it will require attendance at that school to cause due appreciation of some of the flood dangers impending. Referring to the map, Figure 89, it may be noted that the works of the Sanitary District immediately below Riverside, have, or will have, the effect of diverting the total flow of the Desplaines to the west through Joliet, and when the future great flood occurs it will find outlet, in the main, in that direction, and prevent the destruction of property in Chicago.

It is interesting to note that at times the quantity flowing off in some late winter month will exceed the rainfall. This is, of course, due to the melting of snow and thawing of the soil, thus liberating water which fell in some previous month. It will be noted in the records in Table XXXI that the moderate flood of March, 1894, had nearly reached its height before any rainfall, in the form of rain, had occurred, to which the rise of the river could be attributed.

It may be noted that if the maximum flow at Riverside be taken to be 13,500 cubic feet per second, that the said maximum flow is equivalent to a rate of 1.25 inches of rainfall per day over the area of the whole basin, or 21 cubic feet per second per square mile.

It is worth while to examine Figure 92 and note the extent of flood resulting from various rainfalls at different times in the year. Such examination answers the question as to how much rainfall is necessary to cause a flood. It will be seen at once not only that no definite rule can be made, but also the extent to which a definite rule is impracticable and the reasons for such a conclusion. Further

examination will disclose many other interesting and instructive facts involved in the relation of rainfall to flow of the stream.

Reference has been made several times to the extraordinary rainfall of September, 1894, and the small stream flow resulting. In Table XXXI, page 309, the daily stream flow for the month will be noted. The total rainfall for the month at Chicago was 8.28 inches, as previously stated, most all of which occurred in one week, as shown in the following statement:

Date.	Rainfall in inches.
Sept. 3	0.40
Sept. 4	2 95
Sept. 5	0.34
Sept. 6	1.53
Sept. 7	0.01
Sept. 8	1.25
Sept. 9	0 65
Total	7.13

Figure 91, a map, shows the rainfall for this same week at the various stations in and adjacent to the basin, from which it may be seen readily that the rainfall over the whole basin was not materially different from seven (7) inches. This is, of course, an extreme case. There had been but little rainfall for two months previous and the ground was very dry. If the voids or pores of the soil be taken to be one-third of its volume, then it would require a depth of twenty-one inches of soil to absorb this rainfall. It is hardly possible that there could have been any material evaporation during the week in question, because the atmosphere was so continuously humid, nor could vegetation have taken up much of the water in so short a period.

The topography of the basin and the nature of its soil and occupation are all important in connection with the other data.

The map, Figure 89, shows the configuration of the basin. Its general declivity from north to south is about one foot per mile. East and west toward the river the declivity is much steeper, especially east of the river. From the west toward the river it is generally about six feet per mile. The tributary streams have poorly defined beds, and are frequently marshy at their borders. In the upper part of the basin are a number of small lakes and considerable marshy ground.

The soil is generally glacial drift, containing much sand and gravel, the top soil being fertile. The whole basin may be termed a densely populated farming district. There is not much timber except close to the streams. The underlying rock, though at some places close to the surface, is generally twenty feet or more below the surface, and is probably fissured in a manner to readily take up water.

The nature of the basin is quite similar to that of most all the

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streams in the upper Mississippi Valley, and the data pertaining to it may be classed as being closely suggestive of what may be generally expected in the region in question, and may be particularly useful in relation to plans for storing water in catchment basins, and will serve as a guide in the application of catchment basin formulae to the end that results may be reached more intelligently.

APPENDIX.

OFFICE OF DRAINAGE AND WATER SUPPLY COMMISSION,

Chicago, June 13, 1887.

(Desplaines Data, Mem. No. 2.)

"Catchment Basin" Formulae and Their Application.

Mr. S. G. Artingstall, Engineer in Charge, Drainage and Water Supply Investigation—

Sir: I submit herewith several formulae and their application to the Desplaines river and the North Branch of the Chicago river, and their subdivisions:

The formulae are given in the accompanying table. They are of two kinds.

A.

The following data have been collected:

ORDINATES. Measured maximum discharge from certain catchment basins.	ABSCISSAE. Measured area of catchment basins.
Q.	A.
Q.	A.
&c.	&c.

Q and A have been plotted as ordinates and abscissae. Then a curve was passed among the plotted points, passing within varying distances from them. The equation of this curve constitutes any particular "catchment basin" formula. There has not been time to examine into the merits of the data nor into the accuracy with which the curves represent them. These formulae are of the older class. Latterly it has been recognized that Q may have two or more widely differing values while A remains the same. The reasons assigned for this are as follows:

Other things being equal, the maximum discharge will be greater.

(a). As the general declivity of the basin is greater.

(b). As the point of discharge is centrally located with reference to the basin drained.

(c). As the rainfall is more intense, more general and more enduring.

In any given basin, as the Desplaines, for instance (a), (b) and (c) will approximate to constancy, in which event a formula involving only Q and A as variables may be useful.

The formulae of O'Connell and Cooley, according to measurements, apply satisfactorily to the "Desplaines river above bridge below Riverside" (see table XXX). This fact suggests their applicability to various subdivisions of this basin as indicated in the table.

The formulae of Dickins and Fanning are evidently based on data collected from basins physically differing from the Desplaines.

The formulae of O'Connell and Cooley give too great results for the North Branch. This was to be expected, since—

1st. They are quite satisfactory when applied to the Desplaines.

2d. And the North Branch is a much flatter and relatively more narrow basin, in the aggregate and in detail, than the Desplaines.

The validity of the application of these formulae to the subdivisions of the Desplaines does not rest entirely on their satisfactory indications for the whole basin above Riverside. Two measurements of discharge were made in Salt Creek in 1887, one at a high stage at Fullersburg and the other at a low stage near the mouth of the creek. Although these measurements do not furnish the verifications desired they point to the validity of the use of the formulae. Should another flood occur in the creek it would be an easy matter to make enough discharge measurements at Fullersburg and perhaps at other points, to render the verifications satisfactory.

B.

The influence of varying grade, varying rainfall and varying shape of catchment basins being recognized, the following data have been collected, though as in the case of the formulae of Class A there has been no time to examine their merits:

Maximum discharges of various catchment basins.	Areas of basins.	Grades of basins.	Rainfall in basins.	Length of basins.	Breadth of basins.	&c.
Q	A	S	R	L	B	&c.
Q	A	S	R	L	B	&c.
Q	A	S	R	L	B	&c.

Three formulae, given in the table, are based on this class of data; the Dredge, Craig and Burkli-Ziegler formulae.

The Dredge formula is evidently inapplicable.

The Craig formula is intended to apply to natural streams having areas of 50 square miles or more. An ingenious mathematical process provides a more or less rational cognizance of the influence of varying shape of basin. This becomes evident when the results of the formula for the Desplaines and North Branch are compared, nearly equal areas being considered (see table). Cognizance of varying grade and rainfall is taken in the value of N. The form of the formula was determined before considering the data. Excepting N, all the elements of the formula are directly measurable. Their measured values were, for each particular case, substituted, and the formula solved for N. It was found that N varied from about 0.30 to about 2.0 according as the experimental basins were of smaller or greater grade. Very flat basins gave N an average

APPLICATION OF "CATCHMENT BASIN" FORMULAE TO THE DESPLAINES RIVER AND NORTH BRANCH OF CHICAGO RIVER.

DATA.

Q=Maximum flood discharge in cubic feet per second.
A=Area of water shed in square miles.
A_1=Area of water shed in acres.
L=Extreme length of water shed in miles.
B=Average breadth of water shed in miles.
N, C=Co-efficient depending on character of water shed.
S=General grade of water shed per thousand.
R=Function of rainfall—see text.

Area in sq. m.	Length in m.	Breadth in m.	Craig's N	Elements for Burkli-Ziegler Formula. C	R	S	A	Dicken's Formula $Q=825\,A^{3/4}$	Dredge. $Q=1300\frac{A}{L^{2/3}}$	Fanning. $Q=200\,A^{\frac{5}{6}}$	Burkli-Ziegler. $Q=C.R.\sqrt[4]{\frac{S}{A_1}}$	Craig. $Q=440\,B\,N\,\log_e\frac{8L^2}{B}$	O'Connell. $Q=-46.+(2097+458\,A.)^{1/2}$	Cooley. $Q=180\,A^{2/3}$
Desplaines River above Joliet, supposing no flow to Chicago.														
789.0	....	....	....	....	....	....	......	......	.....	......	......	......	......	15360
Desplaines River above bridge just below Riverside.														
633.0	60	10.5	0.33	0.30	0.20	0.28	405120	104110	53693	43205	700	12120	13620	13250
Desplaines River above mouth of Salt Creek.														
490.5	60	8.2	0 33	....	....	....	......	85987	41605	34930	......	9720	12000	11200
Desplaines River above bridge below Riverside, *minus* Salt Creek above dam at Fullersburg.														
522.5	60	8.6	0.33	....	....	....	......	90161	44320	36820	......	10160	12400	11670
Salt creek above dam at Fullersburg.														
110.5	24	4.7	0.35	....	....	....	.....	28117	17265	10090	......	4950	5690	4145
Desplaines River above natural divide south of Brook's Creek.														
439.5	47	9.3	0.33	....	..	....	......	79191	43623	31880	......	10220	11300	10410
Salt Creek above alternative diversion points near Itasca.														
54.0	10 0	5.4	0.35	....	....	....	......	16435	15125	5555	......	4156	3980	2572
68 5	13.0	5.3	0.35	....	....	....	......	19644	16107	6773	......	4502	4480	3013
Desplaines River and Salt Creek above point of diversion on Desplaines (both diversions being made).														
508.0	....	....	....	....	....	....	....	......	......	......	......	......	.....	11460
Desplaines River above bridge below Riverside, Salt Creek being diverted at Itasca and Desplaines at mouth of Brook's Creek.														
125.0	14.0	9.0	0.33	....	....	....	......	30840	27970	11180	......	6743	6950	4500
125.0	{ 12.0 11.0	4.0 4.0	0.33 0.33	....	... .	....	....	....	....	....	....	} 6477	....	....
Desplaines River above Joliet, Salt Creek being diverted at Itasca and Desplaines at mouth of Brook's Creek.														
281.0	35.0	8.0	0.33	....	....	....	......	......	......	21960	......	8260	9075	7722
North Branch of Chicago River, above (1) Fullerton avenue, (2) Bowmanville and (3) Norwood Park.														
156.7	33.0	4.8	0.33	....	....	....	......	......	......	......	......	5230	6780	5230
124.2	29.0	4.2	0.33	....	....	....	......	......	......	......	......	4500	6030	4480
100.0	25.0	4.0	0 33	....	....	....	.....	......	......	.....	......	4140	5410	3880
Desplaines River and N. Br. above Fullerton Ave., Salt Creek being diverted at Itaska and Desplaines River at mouth of Brook's Creek.														
664.7	....	....	....	....	....	....	......	.....	......	......	......	......	......	13700
(The same) reckoned above Bowmanville.														
640 5	....	..	....	....	....	....	......	....	. ...	......	.....	......	.....	13370

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value of 0.33, which has been used in computing the table, even in the case of the North Branch. In this case N=0.20 (about) would probably give more satisfactory results. But inasmuch as the assumption of this value would be in effect the assumption of what it is desired to prove, it has been thought best to use the value of N applied to the Desplaines—the validity of the application being confessedly erroneous and only intended for illustration.

The Burkli-Ziegler formula applies only to small areas, and more especially to paved areas. Its application depends upon evaluating *with enough definiteness*, the following:

1st. The general grade of catchment basins. This cannot, of course, be done in dish-shaped basins. The general grade must be general.

2d. The average intensity of rain during the period of heaviest fall, in cubic feet per second per acre. On the face of it, this requirement limits the use of the formula to small areas.

3d. A co-efficient, ranging from 0.31 to 0.75 depending on the nature of the surface.

The result flowing from one evaluation of these things is given in the table, and demonstrates its inapplicability in the present case. In fact this formula gives dangerous play for judgment.

The application of the catchment basin formula to the case of the Desplaines and North Branch is given in the following table.

Thos. T. Johnston,
Asst. Engr.

Thro' L. E. Cooley,
Principal Asst. Engr.

REMARKS ON MR. JOHNSTON'S MEMORANDUM IN REGARD TO "CATCHMENT BASIN FORMULAE," etc.

Formulae. The one credited to Cooley was derived in 1883 from normal high water cross-sections of several streams of 5 to 110 square miles of watershed and checked on one of 1000 square miles. They were similar as to general form and steepness of drainage areas, being all among low hills, and the ratios of cross-sections all checked very close to A 2-3. The sections were taken when the streams passed out into the Mississippi bottom, above St. Charles, Mo., and where silt deposits had built the banks to mean extreme high water.

The only one of the formulae that is at all rational for basins of unlike form is that of Craig. It is believed that competent study would greatly improve it, as his data is not good and his deductions not fully justified. In fact, it is surprising that any formulae should be proposed from the data cited in their support. No doubt it would be feasible at this time to collect far more competent evidence and establish a better expression than any given.

Application. The application of these formulae gives simply relative indications, and then only so far as the basins may be similar in characteristics. Thus to the Desplaines and Salt creek and even their subdivisions, the relative results may be fairly indicated.

The North Branch, however, and perhaps the Desplaines from Riverside to Joliet, would require lower confinements. Again, the combination of several distinctive basins cannot be regarded as giving the same result as the same area homogeneously distributed in one basin, although the results may be indicative.

One practical conclusion is obvious from the Craig formula, and verified by experience, and that is that long basins give smaller maximums: Thus, to divert Salt creek or what may be left thereof, down Flag creek will diminish flood volume at Joliet and increase the efficacy of the Canal.

Another fact is indicated to which attention is invited: The maximum flood at Joliet will not be diminished, though its duration may be less, after the diversion on the north and the raising of the O-W. dams. This is due in part to the peculiar regimen of the summit divide, referred to under discussions of floods.

This investigation suggests the advisability of collecting data bearing on "Catchment Basin" formulae, and close analysis of individual basins in deducing aggregate results. The application to the flood question in discovering the efficiency of the main drainage channels is obvious.

Respectfully submitted,
L. E. Cooley,
Princpl. Asst. Engr.

TABLE XXXI.

May 1886.

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13	14.42	1364
14	14.42	1364
15	14.67	1549
16	15.32	2118
17	15.27	2070
18	15.07	1886
19	14.97	1803
20	14.92	1758
21	14.77	1626
22	14.27	1256
23	13.52	772
24	13.02	518
25	12.92	478
26	12.62	360
27	12.62	360
28	12.52	310
29	12.52	310
30	12.37	251
31	12.32	236

No regular gauge readings taken previous to May 13 1886. Gauge readings as shown were taken at 7 A.M. The highest reading noted was 7 P.M. - 16th - 15.42 = discharge of 2208 cu ft per sec.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Rainfall in inches
Chicago	Cook	1.00
Sycamore	DeKalb	4.24
Aurora	Kane	5.39
Oswego	Kendall	3.85
Marengo	McHenry	3.13
Winnebago	Winnebago	—

Wisconsin

Station	County	Rainfall in inches
Milwaukee		2.67
Manitowoc	Manitowoc	1.39
Delavan	Walworth	0.95

June 1886

Day	Gauge reading C.C.W.	Discharge cu ft per sec	
1	12.17	188	Gauge readings as shown
2	12.12	168	were taken at 7 A.M.
3	12.42	268	
4	12.32	236	
5	12.22	206	
6	12.07	148	
7	11.97	114	
8	11.87	94	The total precipitation
9	11.87	94	at various points for this
10	11.82	84	month was as follows:—
11	11.77	74	Illinois
12	11.72	64	Station — County — Precipitation inches
13	11.72	64	Chicago — Cook — 0.94
14	11.72	64	Sycamore — DeKalb — 2.27
15	11.67	51	Aurora — Kane — 1.27
16	11.67	51	Oswego — Kendall — 2.17
17	11.77	74	Marengo — McHenry — 1.89
18	11.77	74	
19	11.77	74	
20	11.72	64	
21	11.67	51	
22	11.67	51	Wisconsin
23	11.57	24	Milwaukee — 2.54
24	11.52	14	Manitowoc — Manitowoc — 3.88
25	11.47	7	Delavan — Walworth — 0.70
26	11.55	20	
27	11.52	14	
28	11.55	20	
29	11.77	74	
30	11.87	94	

Total flow = 226,627,200 cu ft equiv. to a Rain fall of 0.155".

July 1886

Day	Gauge reading S. C. D.	Discharge cu ft per sec	
1	11.87	94	Gauge readings as shown
2	12.02	128	were taken at 7 A.M.
3	12.22	206	
4	12.27	221	
5	12.27	221	
6	12.22	206	
7	12.15	180	
8	12.13	172	The total precipitation at
9	12.18	192	various points for this
10	12.04	136	month was as follows:—
11	11.88	96	Illinois
12	11.87	94	Station / County / Precipitation inches
13	11.77	74	Chicago / Cook / 1.53
14	11.76	72	Sycamore / DeKalb / 0.67
15	11.78	76	Aurora / Kane / 0.36
16	11.70	60	Oswego / Kendall / 0.33
17	11.67	51	Marengo / McHenry / 0.81
18	11.58	26	
19	11.58	26	
20	11.54	18	
21	11.52	14	Wisconsin
22	11.47	7	Station / County
23	11.42	2	Milwaukee / / 0.94
24	11.45	5	Manitowoc / Manitowoc / 1.73
25	11.43	3	Delavan / Walworth / 7.40
26	11.52	14	
27	11.40	0	
28	11.27	0	
29	11.17	0	
30	11.12	0	
31	11.10	0	

Total flow = 206 841 600 cu ft equiv. to a Rainfall of 0.142 in.

August 1886

Day	Gauge reading C.C.N	Discharge cuft per sec.	
1	11.31	0	Gauge readings as shown
2	11.30	0	were taken at 7 A.M.
3	11.28	0	
4	11.22	0	
5	11.17	0	
6	11.22	0	
7	11.19	0	
8	11.17	0	The total precipitation
9	11.15	0	at various points for the
10	11.15	0	month was as follows:—
11	11.13	0	Illinois
12	11.14	0	Station County Precipitation (inches)
13	11.11	0	Chicago Cook 3.38
14	11.22	0	Sycamore DeKalb 4.29
15	11.25	0	Aurora Kane 2.97
16	11.42	2	Oswego Kendall 4.27
17	11.34	0	Marengo McHenry 5.85
18	11.35	0	
19	11.36	0	
20	11.52	14	
21	11.41	1	Wisconsin
22	11.67	51	Station County
23	11.57	24	Milwaukee 3.40
24	11.55	20	Manitowoc Manitowoc 1.37
25	11.42	2	Delavan Walworth 2.79
26	11.36	0	
27	11.27	0	
28	11.27	0	
29	11.52	14	
30	11.57	24	
31	11.52	14	

Total flow = 14342 400 cuft. equiv. to a Rainfall of .0098 inches

September 1886

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	11.72	64	Gauge readings as shown		
2	11.77	74	were taken at 7 A.M.		
3	11.52	14			
4	11.47	7			
5	11.37	0			
6	11.42	2			
7	11.28	0			
8	11.27	0	The total precipitation		
9	11.28	0	at various points for this		
10	11.30	0	month was as follows:—		
11	11.35	0		Illinois	
12	11.35	0	Station	County	Precipitation inches
13	11.42	2	Chicago	Cook	6.93
14	11.40	0	Sycamore	DeKalb	3.23
15	11.34	0	Aurora	Kane	5.60
16	11.27	0	Oswego	Kendall	4.53
17	11.27	0	Marengo	McHenry	2.25
18	11.29	0			
19	11.42	2			
20	11.41	1			
21	11.97	114		Wisconsin	
22	12.02	128	Station	County	Precip
23	11.62	36	Milwaukee		2.38
24	11.50	10	Manitowoc	Manitowoc	6.68
25	11.43	3	Delavan	Walworth	2.70
26	11.38	0			
27	11.49	9			
28	11.35	0			
29	11.32	0			
30	11.32	0			

Total flow = 40,262,400 cu ft equiv. to a Rainfall of 0.028 in.

October 1886

Day	Gauge reading C.C.B.	Discharge cu ft per sec.	
1	11.34	0	Gauge readings as shown
2	11.34	0	were taken at 7 A.M.
3	11.34	0	
4	11.36	0	
5	11.32	0	
6	11.33	0	
7	11.17	0	
8	11.17	0	The total precipitation
9	11.07	0	at various points for this
10	11.07	0	month was as follows:—
11	11.07	0	Illinois
12	11.07	0	Station County Precipitation inches
13	11.07	0	Chicago Cook 1.42
14	11.07	0	Sycamore DeKalb 2.26
15	11.04	0	Aurora Kane 1.80
16	11.09	0	Oswego Kendall 1.20
17	11.07	0	Marengo McHenry 2.55
18	11.09	0	
19	11.17	0	
20	11.17	0	
21	11.17	0	Wisconsin
22	11.07	0	Station County Precip
23	11.07	0	Milwaukee 2.31
24	11.07	0	Manitowoc Manitowoc 3.86
25	11.07	0	Delavan Walworth 1.19
26	11.09	0	
27	11.40	0	
28	11.49	9	
29	11.75	70	
30	11.62	36	
31	11.48	8	

Total flow = 10,627,200 cu ft equiv to a Rainfall of .0073 in.

November 1886

Day	Gauge Reading C.C.N.	Discharge cu ft per sec
1	11.40	0
2	11.37	0
3	11.15	0
4	11.30	0
5	11.12	0
6	11.07	0
7	11.07	0
8	11.09	0
9	11.17	0
10	11.27	0
11	11.27	0
12	11.32	0
13	11.27	0
14	11.27	0
15	11.27	0
16	11.27	0
17	11.27	0
18	11.27	0
19	11.07	0
20	11.32	0
21	11.47	7
22	11.46	6
23	11.17	0
24	11.17	0
25	11.07	0
26	11.05	0
27	11.19	0
28	11.07	0
29	11.07	0
30	11.07	0

Gauge readings as shown were taken at 7 A.m.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.66
Sycamore	DeKalb	0.96
Aurora	Kane	1.26
Oswego	Kendall	0.86
Marengo	McHenry	0.98

Wisconsin

Station	County	Precip
Milwaukee		1.62
Manitowoc	Manitowoc	2.47
Delavan	Walworth	1.36

Total flow = 1 123 200 cu ft equiv. to a Rainfall of .00077"

December 1886

Day	Gauge reading. CCN.	Discharge cu ft per sec.	
1	11.12	0	Gauge readings as shown
2	10.97	0	were taken at 7 a.m.
3	10.95	0	
4	10.87	0	
5	10.97	0	
6	10.82	0	
7	10.82	0	
8	10.87	0	The total precipitation
9	10.87	0	at various points for this
10	10.87	0	month was as follows:—
11	10.87	0	Illinois
12	10.97	0	Station County Precipitation inches
13	11.32	0	Chicago Cook 1.26
14	11.32	0	Sycamore DeKalb 1.54
15	11.27	0	Aurora Kane 1.18
16	11.17	0	Oswego Kendall 1.01
17	10.77	0	Marengo McHenry 1.13
18	11.07	0	
19	11.02	0	
20	11.02	0	
21	11.37	0	Wisconsin
22	11.17	0	Station County Precip.
23	11.17	0	Milwaukee 2.03
24	11.15	0	Manitowoc Manitowoc 1.45
25	11.09	0	Delavan Walworth —
26	10.95	0	
27	10.95	0	
28	10.97	0	
29	10.92	0	
30	11.02	0	
31	10.97	0	

Total flow = 0.

January 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec.
1	10.97	0
2	11.09	0
3	11.17	0
4	11.30	0
5	11.20	0
6	11.20	0
7	11.20	0
8	11.20	0
9	11.20	0
10	11.25	0
11	11.20	0
12	11.00	0
13	11.10	0
14	11.10	0
15	11.15	0
16	11.10	0
17	11.15	0
18	11.30	0
19	11.15	0
20	11.05	0
21	11.10	0
22	11.30	0
23	15.50	2280
24	15.25	2050
25	14.35	1315
26	14.28	1264
27	15.45	2235
28	14.60	1500
29	14.60	1500
30	14.40	1350
31	14.55	1450

Gauge readings as shown were taken at 7 a.m.
The highest reading noted this month was 7 P.M.-23rd 16.20 = 3040 cu ft per sec.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	3.13
Sycamore	DeKalb	3.93
Aurora	Kane	4.36
Oswego	Kendall	2.98
Marengo	McHenry	3.59

Wisconsin

Station	County	Precip.
Milwaukee		2.66
Manitowoc	Manitowoc	1.82
Delavan	Walworth	4.05
Beloit	Rock	2.69

Total flow = 1291,161,600 cu ft equiv. to a Rainfall of 0.89 in.

February 1887.

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	14.50	1420
2	14.20	1200
3	14.00	1060
4	13.80	940
5	13.60	820
6	13.30	650
7	13.30	650
8	17.20	4400
9	20.00	9650
10	19.70	8960
11	18.80	7100
12	17.90	5470
13	17.90	5470
14	16.95	4035
15	16.30	3160
16	16.05	2865
17	15.75	2535
18	18.00	5650
19	18.15	5905
20	17.40	4690
21	16.85	3890
22	16.30	3160
23	15.70	2480
24	15.30	2100
25	15.10	1910
26	14.20	1200
27	14.80	1650
28	14.75	1610

Gauge readings as shown were taken at 7 A.M.
The highest reading noted was 7 P.M.—9th— 20.20 = discharge of 10120 cu ft per sec

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	5.10
Sycamore	DeKalb	4.50
Aurora	Kane	5.86
Oswego	Kendall	4.29
Marengo	McHenry	4.82

Wisconsin

Station	County	Precip.
Milwaukee		3.22
Manitowoc	Manitowoc	3.55
Delavan	Walworth	5.34
Beloit	Rock	5.16

Total flow = 8176,032,000 cu ft equiv. to a Rainfall of 5.59 in.

March 1887

Day	Gauge reading C.C.D.	Discharge cuft per sec	
1	13.90	1000	Gauge readings as shown
2	14.30	1280	were taken at 7 a.m.
3	14.90	1740	The highest reading noted was
4	15.05	1870	7 P.m. - 9th - 16.35 = discharge
5	15.40	2190	of 3220 cuft per sec.
6	15.10	1910	
7	14.90	1740	
8	15.90	2700	The total precipitation
9	16.30	3160	at various points for this
10	16.25	3100	month was as follows:—
11	15.95	2755	Illinois
12	15.00	1830	Station — County — Precipitation inches
13	15.60	2370	Chicago — Cook — 0.89
14	15.95	2755	Sycamore — DeKalb — 0.86
15	15.40	2190	Aurora — Kane — 1.06
16	14.90	1740	Oswego — Kendall — 0.80
17	15.05	1870	Marengo — McHenry — 1.01
18	14.70	1570	
19	14.15	1160	
20	13.90	1000	
21	13.70	880	Wisconsin
22	13.50	760	Station — County — Precip.
23	13.30	650	Milwaukee — — 1.25
24	13.10	550	Manitowoc — Manitowoc — 0.93
25	13.00	510	Delavan — Walworth — 1.85
26	12.95	490	Beloit — Rock — 1.36
27	12.80	430	
28	12.60	350	
29	12.70	400	
30	12.45	280	
31	12.50	300	

Total flow = 3933,792,000 cuft equiv. to a Rainfall of 2.64 in.

April 1887

Day	Gauge reading C.C.N.	Discharge cu ft per sec	
1	12.60	350	Gauge readings as shown
2	12.75	415	were taken at 7 a.m.
3	12.95	490	
4	13.05	530	
5	12.95	490	
6	12.90	470	
7	12.80	430	
8	12.85	450	The total precipitation
9	12.75	415	at various points for this
10	12.70	400	month was as follows:—
11	12.60	350	Illinois
12	12.50	300	Station — County — Precipitation inches
13	12.50	300	Chicago — Cook — 0.46
14	12.40	260	Sycamore — DeKalb — 1.08
15	12.30	230	Aurora — Kane — 0.82
16	12.20	200	Oswego — Kendall — 0.48
17	12.25	215	Marengo — McHenry — 1.55
18	12.15	180	
19	12.15	180	
20	12.00	120	
21	12.10	160	Wisconsin
22	12.05	140	Station — County — Precip.
23	12.00	120	Milwaukee — — 1.05
24	12.10	160	Manitowoc — Manitowoc — 0.96
25	12.40	260	Delavan — Walworth — 0.88
26	12.30	230	Beloit — Rock — 1.08
27	12.20	200	
28	12.30	230	
29	12.30	230	
30	12.25	215	

Total flow = 753,408,000 cu ft equiv. to a Rainfall of 0.52"

May 1887.

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	12.20	200	Gauge readings as shown
2	12.05	140	were taken at 7 a.m.
3	12.00	120	
4	11.95	110	
5	11.90	100	
6	11.90	100	
7	11.95	110	
8	11.90	100	The total precipitation at
9	11.80	80	various points for this
10	11.85	90	month was as follows:—
11	11.75	70	Illinois
12	11.75	70	Station County Precipitation inches
13	11.75	70	Chicago Cook 1.38
14	11.70	60	Sycamore DeKalb 0.95
15	11.70	60	Aurora Kane 3.02
16	11.75	70	Oswego Kendall 2.78
17	11.65	45	Marengo McHenry 0.95
18	11.60	30	
19	11.55	20	
20	11.60	30	
21	11.65	45	Wisconsin
22	11.70	60	Station County Precip.
23	11.70	60	Milwaukee 1.80
24	11.75	70	Manitowoc Manitowoc 1.04
25	11.65	45	Delavan Walworth 3.11
26	11.60	30	Beloit Rock 0.99
27	11.65	45	
28	11.65	45	
29	11.55	20	
30	11.55	20	
31	11.60	30	

Total flow = 185,328,000 cu ft equiv. to a Rainfall of 0.126 in

June 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	11.65	45	Gauge readings as shown
2	11.60	30	were taken at 7 a.m.
3	11.50	10	
4	11.50	10	
5	11.55	20	
6	11.65	45	
7	11.65	45	
8	11.55	20	The total precipitation
9	11.50	10	at various points for this
10	11.50	10	month was as follows:—
11	11.45	5	Illinois
12	11.40	0	Station — County — Precipitation inches
13	11.45	5	Chicago — Cook — 1.63
14	11.40	0	Sycamore — DeKalb — 1.12
15	11.35	0	Aurora — Kane — 0.58
16	11.35	0	Oswego — Kendall — 0.29
17	11.30	0	Marengo — McHenry — 1.23
18	11.30	0	
19	11.20	0	
20	11.05	0	
21	11.40	0	Wisconsin
22	11.40	0	Station — County — Precip.
23	11.40	0	Milwaukee — 0.81
24	11.40	0	Manitowoc — Manitowoc — 1.32
25	11.30	0	Delavan — Walworth — 0.51
26	11.20	0	Beloit — Rock — 0.41
27	11.15	0	
28	11.10	0	
29	11.20	0	
30	11.20	0	

Total flow = 22 032 000 cu ft equiv. to a Rainfall of 0.015 in.

July 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	11.20	0
2	11.10	0
3	11.20	0
4	11.25	0
5	11.15	0
6	11.10	0
7	11.05	0
8	11.10	0
9	11.05	0
10	11.00	0
11	11.00	0
12	11.00	0
13	11.10	0
14	11.05	0
15	11.05	0
16	11.05	0
17	11.00	0
18	12.95	490
19	12.90	470
20	12.95	490
21	12.85	450
22	12.80	430
23	12.80	430
24	12.80	430
25	12.75	415
26	12.70	400
27	12.70	400
28	12.65	375
29	12.60	350
30	12.55	325
31	12.20	200

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.05
Sycamore	DeKalb	3.12
Aurora	Kane	2.34
Oswego	Kendall	1.21
Marengo	McHenry	2.70

Wisconsin

Station	County	Precip.
Milwaukee		5.21
Manitowoc	Manitowoc	1.90
Delavan	Walworth	3.83
Beloit	Rock	1.61

Total flow = 488,592,000 cu ft equiv. to a Rainfall of 0.334 in.

August 1887

Day	Gauge reading C.C.N.	Discharge cu. ft. per sec.
1	12.10	160
2	12.00	120
3	11.95	110
4	11.85	90
5	11.80	80
6	11.70	60
7	11.75	70
8	11.70	60
9	11.70	60
10	11.70	60
11	11.80	80
12	11.80	80
13	11.80	80
14	12.05	140
15	12.00	120
16	11.95	110
17	11.95	110
18	11.90	100
19	11.90	100
20	11.85	90
21	11.95	110
22	12.00	120
23	11.95	110
24	11.90	100
25	11.85	90
26	11.90	100
27	11.95	110
28	11.85	90
29	11.80	80
30	11.85	90
31	11.85	90

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	3.35
Sycamore	DeKalb	3.61
Aurora	Kane	3.79
Oswego	Kendall	3.48
Marengo	McHenry	4.85

Wisconsin

Station	County	Precip.
Milwaukee		2.25
Manitowoc	Manitowoc	2.76
Delavan	Walworth	3.63
Beloit	Rock	5.79

Total flow = 256 608 000 cu. ft. equiv. to a Rainfall of 0.175 in.

September 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	11.85	90	Gauge readings as shown
2	11.80	80	were taken at 7 a.m.
3	11.80	80	
4	11.80	80	
5	11.85	90	
6	11.85	90	
7	11.85	90	
8	11.85	90	The total precipitation
9	11.85	90	at various points for this
10	11.85	90	month was as follows:—
11	11.85	90	Illinois
12	11.85	90	Station — County — Precipitation inches
13	11.90	100	Chicago — Cook — 4.03
14	12.10	160	Sycamore — DeKalb — 3.27
15	12.15	180	Aurora — Kane — 4.33
16	12.10	160	Oswego — Kendall — 2.70
17	12.05	140	Marengo — McHenry — 4.61
18	12.00	120	
19	12.00	120	
20	12.00	120	
21	12.00	120	Wisconsin
22	12.05	140	Station — County — Precip.
23	12.00	120	Milwaukee — — 4.36
24	12.00	120	Manitowoc — Manitowoc — 4.74
25	12.00	120	Delavan — Walworth — 4.29
26	12.00	120	Beloit — Rock — 5.17
27	12.20	200	
28	12.15	180	
29	12.15	180	
30	12.25	215	

Total flow = 316,656 000 cu ft equiv. to a Rainfall of 0.216 in.

October 1887

Day	Gauge reading E.C.W.	Discharge cu ft per sec
1	12.35	245
2	12.55	325
3	12.65	375
4	12.65	375
5	12.70	400
6	12.70	400
7	12.75	415
8	12.80	430
9	12.85	450
10	12.80	430
11	12.75	415
12	12.75	415
13	12.70	400
14	12.70	400
15	12.70	400
16	12.65	375
17	12.60	350
18	12.60	350
19	12.55	325
20	12.45	280
21	12.35	245
22	12.35	245
23	12.45	280
24	12.55	325
25	12.55	325
26	12.50	300
27	12.45	280
28	12.45	280
29	12.40	260
30	12.40	260
31	12.40	260

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.03
Sycamore	DeKalb	2.80
Aurora	Kane	3.54
Oswego	Kendall	2.34
Marengo	McHenry	[illegible].75

Wisconsin

Station	County	Precip.
Milwaukee		2.43
Manitowoc	Manitowoc	3.37
Delavan	Walworth	2.47
Beloit	Rock	2.00

Total flow = 917 136000 cu ft equiv. to a Rainfall of 0.626 in.

November 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	12.35	245	Gauge readings as shown
2	12.35	245	were taken at 7 A.M.
3	12.35	245	
4	12.35	245	
5	12.35	245	
6	12.40	260	
7	12.45	280	
8	12.55	325	The total precipitation at
9	12.55	325	various points for the
10	12.55	325	month was as follows:—
11	12.50	300	Illinois
12	12.45	280	Station — County — Precipitation inches
13	12.45	280	Chicago — Cook — 2.41
14	12.45	280	Sycamore — DeKalb — 1.49
15	12.40	260	Aurora — Kane — 2.21
16	12.40	260	Oswego — Kendall — 1.78
17	12.35	245	Marengo — McHenry — 1.87
18	12.35	245	
19	12.30	230	
20	12.30	230	
21	12.25	215	Wisconsin
22	12.30	230	Station — County — Precip.
23	12.35	245	Milwaukee — — 0.85
24	12.40	260	Manitowoc — Manitowoc — 1.17
25	12.45	280	Delavan — Walworth — 1.21
26	12.55	325	Beloit — Rock — 1.45
27	—	—	
28	—	—	
29	—	—	
30	—	—	

December 1887

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	—		Gauge readings as shown
2	—		were taken at 7 am.
3	—		
4	12.75	415	
5	12.80	430	
6	12.80	430	
7	13.50	760	
8	13.85	970	The total precipitation at
9	13.90	1000	various points for this
10	13.85	970	month was as follows:—
11	13.85	970	Illinois
12	13.85	970	Station County Precipitation inches
13	13.80	940	Chicago Cook 3.67
14	13.75	910	Sycamore DeKalb 3.02
15	13.70	880	Aurora Kane 4.25
16	13.70	880	Oswego Kendall 3.38
17	13.70	880	Marengo McHenry 3.31
18	13.70	880	
19	13.75	910	
20	13.80	940	
21	13.85	970	Wisconsin
22	13.90	1000	Station County Precip.
23	13.80	940	Milwaukee 4.57
24	13.80	940	Manitowoc Manitowoc 2.91
25	13.75	910	Delavan Walworth 4.60
26	13.70	880	Beloit Rock 3.86
27	13.70	880	
28	13.65	850	
29	13.65	850	
30	13.60	820	
31	13.60	820	

January 1888					
Day	Gauge reading CCN	Discharge cuft per sec			
1	13.60	820	Gauge readings as shown		
2	13.60	820	were taken at 7 A.M.		
3	13.60	820			
4	13.65	850			
5	13.65	850			
6	13.65	850			
7	13.65	850			
8	13.65	850	The total precipitation		
9	13.65	850	at various points for the		
10	13.60	820	month was as follows:—		
11	13.60	820	Illinois		
12	13.60	820	Station	County	Precipitation inches
13	13.55	790	Chicago	Cook	1.56
14	13.55	790	Sycamore	DeKalb	1.01
15	13.50	760	Aurora	Kane	1.40
16	13.50	760	Oswego	Kendall	1.46
17	13.50	760	Marengo	McHenry	1.24
18	13.45	730			
19	13.45	730			
20	13.40	700			
21	13.40	700	Wisconsin		
22	13.35	675	Station	County	Precip.
23	13.35	675	Milwaukee		1.41
24	13.30	650	Manitowoc	Manitowoc	1.87
25	13.30	650	Delavan	Walworth	1.22
26	13.30	650	Beloit	Rock	1.16
27	13.30	650			
28	13.30	650			
29	13.25	625			
30	13.20	600			
31	13.25	625			

Total flow = 2003,616,000 cuft equiv. to a Rainfall of 1.37 in.

February 1888

Day	Gauge reading C.C.N.	Discharge cuft per sec	
1	13.35	675	Gauge readings as shown were
2	13.40	700	taken at 7 a.m.
3	13.45	730	The highest reading recorded for the
4	13.40	700	month was 7 P.M. – 29th – 17.10 =
5	13.35	675	discharge of 4250 cuft per sec
6	13.30	650	
7	13.30	650	
8	13.25	625	The total precipitation
9	13.25	625	at various points for the
10	13.20	600	month was as follows:—
11	13.20	600	Illinois
12	13.25	625	Station — County — Precipitation inches
13	13.35	675	Chicago — Cook — 1.51
14	13.35	675	Sycamore — DeKalb — 1.16
15	13.40	700	Aurora — Kane — 1.56
16	13.45	730	Oswego — Kendall — 1.54
17	13.50	760	Marengo — McHenry — 1.17
18	13.60	820	
19	13.90	1000	
20	14.45	1385	
21	15.85	2645	Wisconsin
22	15.65	2425	Station — County — Precip.
23	14.85	1695	Milwaukee — 1.08
24	15.10	1910	Manitowoc — Manitowoc — 3.60
25	16.60	3550	Delavan — Walworth — 0.87
26	16.70	3690	Beloit — Rock — 1.12
27	16.70	3690	
28	16.85	3890	
29	17.00	4110	

Total flow = 3646,512,000 cuft equiv. to a Rainfall of 2.50 inches

March 1888

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	16.95	4035
2	16.85	3895
3	16.75	3755
4	16.60	3550
5	16.30	3160
6	16.00	2810
7	15.60	2370
8	15.20	2000
9	14.85	1695
10	14.85	1695
11	14.65	1535
12	14.45	1385
13	14.35	1315
14	14.40	1350
15	14.35	1315
16	14.30	1280
17	14.40	1350
18	14.40	1350
19	14.85	1695
20	15.20	2000
21	16.30	3160
22	17.10	4250
23	16.85	3890
24	16.70	3690
25	16.75	3755
26	16.85	3890
27	16.90	3960
28	16.70	3690
29	16.20	3040
30	15.80	2590
31	15.65	2425

Gauge readings as shown were taken at 7 A.M. The highest reading recorded for the month was 7 P.M. - 21st - 17.25 = discharge of 4470 cu ft per sec

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.99
Sycamore	DeKalb	2.59
Aurora	Kane	3.19
Oswego	Kendall	2.77
Marengo	McHenry	2.34

Wisconsin

Station	County	Precip.
Milwaukee		2.25
Manitowoc	Manitowoc	3.69
Delavan	Walworth	1.70
Beloit	Rock	2.83

Total flow = 7074,432,000 cu ft equiv. to a Rainfall of 4.84 in.

September 1888.

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	—	—
2	11.95	110
3	11.90	100
4	11.85	90
5	11.80	80
6	11.70	60
7	11.60	30
8	11.60	30
9	11.55	20
10	11.50	10
11	11.45	5
12	11.40	0
13	11.40	0
14	11.35	0
15	11.30	0
16	11.35	0
17	11.40	0
18	11.50	10
19	11.50	10
20	11.45	5
21	11.35	0
22	11.25	0
23	11.20	0
24	11.15	0
25	11.10	0
26	11.05	0
27	11.05	0
28	11.00	0
29	11.00	0
30	11.00	0

Total flow = —

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.98
Sycamore	DeKalb	1.09
Aurora	Kane	1.89
Oswego	Kendall	1.22
Marengo	McHenry	1.00

Wisconsin

Station	County	Precip
Milwaukee		0.99
Manitowoc	Manitowoc	3.63
Delavan	Walworth	0.69
Beloit	Rock	1.01

October 1888

Day	Gauge reading C.C.N.	Discharge cu ft per sec	
1	10.95	0	Gauge readings as shown
2	10.90	0	were taken at 7 a.m.
3	10.90	0	
4	10.85	0	
5	10.80	0	
6	10.80	0	
7	10.80	0	
8	10.80	0	The total precipitation at
9	10.75	0	various points for this month
10	10.75	0	was as follows:—
11	10.75	0	Illinois
12	10.80	0	Station County Precipitation inches
13	10.85	0	Chicago Cook 2.95
14	10.90	0	Sycamore DeKalb 2.37
15	10.95	0	Aurora Kane 3.10
16	10.98	0	Oswego Kendall 2.73
17	10.95	0	Marengo McHenry 1.70
18	10.95	0	
19	10.95	0	
20	10.95	0	
21	10.95	0	Wisconsin
22	10.95	0	Station County Precip
23	11.00	0	Milwaukee 1.18
24	11.00	0	Manitowoc Manitowoc 0.96
25	11.00	0	Delavan Walworth 1.79
26	11.00	0	Beloit Rock —
27	11.00	0	
28	10.95	0	
29	10.90	0	
30	10.85	0	
31	10.85	0	

Total flow = 0

November 1888

Day	Gauge reading C.C.N.	Discharge cu ft per sec	
1	10.85	0	Gauge readings as shown
2	10.85	0	were taken at 7 A.M.
3	10.85	0	
4	10.85	0	
5	10.90	0	
6	10.95	0	
7	11.00	0	
8	11.00	0	The total precipitation
9	11.00	0	at various points for this
10	11.00	0	month was as follows:—
11	11.00	0	Illinois
12	11.00	0	Station County Precipitation inches
13	11.00	0	Chicago Cook 2.89
14	11.00	0	Sycamore DeKalb 1.80
15	11.00	0	Aurora Kane 3.27
16	11.00	0	Oswego Kendall 3.21
17	11.00	0	Marengo McHenry 1.97
18	11.00	0	
19	11.00	0	
20	11.00	0	
21	11.00	0	Wisconsin
22	10.95	0	Station County Precip.
23	10.95	0	Milwaukee 1.46
24	10.95	0	Manitowoc Manitowoc 1.61
25	10.95	0	Delavan Walworth 2.01
26	10.95	0	Beloit Rock —
27	10.85	0	
28	10.75	0	
29	10.65	0	
30	10.55	0	

Total flow = 0

December 1888

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	10.45	0
2	10.40	0
3	10.35	0
4	10.30	0
5	10.25	0
6	10.20	0
7	10.15	0
8	10.10	0
9	10.05	0
10	10.00	0
11	10.00	0
12	9.90	0
13	9.80	0
14	9.75	0
15	9.65	0
16	9.60	0
17	9.60	0
18	9.55	0
19	9.50	0
20	9.50	0
21	9.45	0
22	9.50	0
23	9.55	0
24	9.65	0
25	9.70	0
26	9.75	0
27	9.80	0
28	9.95	0
29	10.10	0
30	10.30	0
31	10.40	0

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.94
Sycamore	DeKalb	2.16
Aurora	Kane	2.61
Oswego	Kendall	2.22
Marengo	McHenry	1.87

Wisconsin

Station	County	Precip.
Milwaukee		1.97
Manitowoc	Manitowoc	2.14
Delavan	Walworth	2.56
Beloit	Rock	—

Total flow = 0.

January 1889

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	10.55	0
2	10.70	0
3	10.85	0
4	10.95	0
5	11.10	0
6	11.10	0
7	11.10	0
8	11.15	0
9	11.25	0
10	11.35	0
11	11.50	10
12	11.60	30
13	11.75	70
14	11.85	90
15	11.95	110
16	12.10	160
17	12.30	230
18	12.50	300
19	12.70	400
20	12.90	470
21	12.85	450
22	12.75	415
23	12.65	375
24	12.55	325
25	12.45	280
26	12.35	245
27	12.35	245
28	12.25	215
29	12.15	180
30	12.05	140
31	11.95	110

Gauge readings as shown were taken at 9 A.M.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.64
Sycamore	DeKalb	1.13
Aurora	Kane	2.06
Oswego	Kendall	1.57
Marengo	McHenry	1.86

Wisconsin

Station	County	Precip.
Milwaukee		1.95
Manitowoc	Manitowoc	2.68
Hayward		—
Oshkosh	Winnebago	2.89
Delavan	Walworth	2.07
Beloit	Rock	—
Fond du Lac	Fond du Lac	2.24

Total flow = 419 040 000 cu ft equiv to a Rainfall of 0.287 in.

February 1889

Day	Gauge reading C.C.W.	Discharge cu ft per sec	
1	11.85	90	Gauge readings as shown
2	11.75	70	were taken at 7 AM.
3	11.65	45	
4	11.55	20	
5	11.45	5	
6	11.40	0	
7	11.30	0	
8	11.20	0	The total precipitation
9	11.15	0	at various points for this
10	11.00	0	month was as follows:—
11	10.95	0	Illinois
12	10.85	0	Station County Precipitation inches
13	10.75	0	Chicago Cook 1.31
14	10.65	0	Sycamore DeKalb 0.86
15	10.65	0	Aurora Kane 1.32
16	10.75	0	Oswego Kendall 1.03
17	10.85	0	Marengo McHenry 1.21
18	10.85	0	
19	10.75	0	
20	10.65	0	
21	10.55	0	Wisconsin
22	10.45	0	Station County Precip.
23	10.35	0	Milwaukee 2.00
24	10.30	0	Manitowoc Manitowoc 2.56
25	10.25	0	Oshkosh Winnebago 3.18
26	10.20	0	Delavan Walworth 2.23
27	10.15	0	Fond du Lac Fond du Lac 2.67
28	10.15	0	

Total flow = 19 872 000 cu ft equiv. to a Rainfall of 0.014 in.

March 1889

Day	Gauge Reading CCH.	Discharge cu ft per sec	
1	10.20	0	Gauge readings as shown
2	10.30	0	were taken at 7 AM.
3	10.40	0	
4	10.85	0	
5	11.30	0	
6	13.10	550	
7	13.25	625	
8	13.25	625	The total precipitation at
9	13.20	600	various points for this
10	13.20	600	month was as follows:—
11	13.10	550	Illinois
12	12.95	490	Station — County — Precipitation inches
13	12.85	450	Chicago — Cook — 1.43
14	12.70	400	Sycamore — DeKalb — 1.39
15	12.60	350	Aurora — Kane — 1.47
16	12.50	300	Oswego — Kendall — 1.28
17	12.45	280	Marengo — McHenry — 1.56
18	12.35	245	
19	12.25	215	
20	12.15	180	
21	12.00	120	Wisconsin
22	11.95	110	Station — County — Precip.
23	11.85	90	Milwaukee — — 1.07
24	11.75	70	Manitowoc — Manitowoc — 0.53
25	11.65	45	Hayward — — 0.80
26	11.55	20	Oshkosh — Winnebago — 0.68
27	11.50	10	Delavan — Walworth — 1.86
28	11.65	45	Fond du Lac — Fond du Lac — 0.47
29	11.75	70	
30	11.85	90	
31	11.85	90	

Total flow = 623 808 000 cu ft equiv. to a Rainfall of 0.426 in.

April 1889

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	11.90	100	Gauge readings as shown
2	12.00	120	were taken at 7 am.
3	12.15	180	
4	12.05	140	
5	11.95	110	
6	11.85	90	
7	11.75	70	
8	11.65	45	The total precipitation at
9	11.55	20	various points for this month
10	11.45	5	was as follows:—
11	11.50	10	Illinois
12	13.60	820	Station · County · Precipitation inches
13	14.20	1200	Chicago · Cook · 2.35
14	14.40	1350	Sycamore · DeKalb · 3.47
15	14.35	1315	Aurora · Kane · 2.63
16	14.10	1120	Oswego · Kendall · 2.23
17	13.80	940	Marengo · McHenry · 2.48
18	13.80	940	
19	14.00	1060	
20	14.15	1160	
21	14.30	1280	Wisconsin
22	14.20	1200	Station · County · Precip.
23	14.00	1060	Milwaukee · · 2.40
24	13.90	1000	Manitowoc · Manitowoc · 1.06
25	13.75	910	Hayward · · 0.54
26	13.45	730	Oshkosh · Winnebago · 0.72
27	13.20	600	Delavan · Walworth · 2.53
28	13.20	600	Fond du Lac · Fond du Lac · 1.02
29	13.00	510	
30	12.65	375	

Total flow = 1646,784 000 cu ft equiv. to a Rainfall of 1.13 in.

May 1889

Day	Gauge reading C.C.B.	Discharge cu ft. pr sec.	
1	12.30	230	Gauge readings were taken
2	12.20	200	at 7 AM.
3	12.10	160	
4	11.95	110	
5	11.85	90	
6	11.75	70	
7	11.65	45	
8	11.55	20	The total precipitation
9	11.45	5	at various points for the
10	11.35	0	month was as follows:—
11	11.25	0	Illinois
12	11.65	45	Station County Precipitation inches
13	12.10	160	Chicago Cook 5.38
14	12.75	415	Sycamore DeKalb 5.17
15	12.85	450	Aurora Kane 3.82
16	12.90	470	Oswego Kendall 3.12
17	12.80	430	Marengo McHenry 4.09
18	12.80	430	
19	12.90	470	
20	12.90	470	
21	12.80	430	Wisconsin
22	12.65	375	Station County Precip
23	12.55	325	Milwaukee 5.64
24	12.45	280	Manitowoc Manitowoc 4.09
25	12.35	250	Hayward 2.50
26	12.20	200	Oshkosh Winnebago 3.52
27	12.00	120	Delavan Walworth 5.25
28	11.90	100	Fond du lac Fond du lac 4.29
29	11.80	80	
30	11.90	100	
31	11.95	110	

Total flow = 573 696 000 cu ft equiv. to a Rainfall of 0.39"

June 1889

Day	Gauge reading C.C.S.	Discharge cu ft per sec			
1	11.90	100	Gauge readings as shown		
2	11.80	80	were taken at 6:30 a.m.		
3	11.70	60			
4	11.60	30			
5	11.50	10			
6	11.55	20			
7	11.65	45			
8	11.80	80	The total precipitation		
9	11.80	80	at various points for this		
10	12.00	120	month was as follows:—		
11	12.20	200		Illinois	
12	12.40	260	Station	County	Precipitation inches
13	12.75	415	Chicago	Cook	2.93
14	13.20	600	Sycamore	DeKalb	1.50
15	13.85	970	Aurora	Kane	4.38
16	13.95	1030	Oswego	Kendall	4.98
17	13.70	880	Marengo	McHenry	3.25
18	14.00	1060			
19	14.95	1785			
20	15.10	1910			
21	15.45	2235		Wisconsin	
22	14.65	1535	Station	County	Precip.
23	14.20	1200	Milwaukee		5.21
24	13.75	910	Manitowoc	Manitowoc	4.28
25	13.65	850	Hayward		2.15
26	13.70	880	Oshkosh	Winnebago	3.49
27	13.80	940	Delavan	Walworth	3.21
28	13.90	1000	Fond du Lac	Fond du Lac	4.18
29	14.00	1060			
30	14.00	1060			

Total flow = 1849 392 000 cu ft equiv. to a Rainfall of 1.26 in.

July 1889

Day	Gauge reading C.C.H.	Discharge cu ft per sec	
1	13.95	1030	Gauge readings as shown
2	13.65	850	were taken up to the 6th at 6:30 A.M.
3	13.55	790	& after that at 7 A.M.
4	13.45	730	
5	13.75	910	
6	13.85	970	
7	11.85	90	
8	11.65	45	The total precipitation
9	11.45	5	at various points for this
10	11.35	0	month was as follows:—
11	11.25	0	Illinois
12	11.20	0	Station County Precipitation inches
13	11.25	0	Chicago Cook 9.56
14	11.85	90	Sycamore DeKalb 4.48
15	13.20	600	Aurora Kane 5.08
16	13.80	940	Oswego Kendall 4.44
17	13.35	675	Marengo McHenry 3.44
18	13.00	510	
19	12.85	450	
20	12.65	375	
21	12.55	325	Wisconsin
22	12.35	245	Station County Precip.
23	12.10	160	Milwaukee 3.08
24	11.95	110	Manitowoc Manitowoc 2.24
25	11.85	90	Hayward 1.29
26	11.75	70	Oshkosh Winnebago —
27	11.65	45	Delavan Walworth 4.00
28	16.65	3620	Fond du Lac Fond du Lac 2.32
29	14.95	1785	
30	14.85	1695	
31	14.35	1315	

Total flow = 1600 128 000 cu ft equiv. to a Rainfall of 1.09 in.

August 1884

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	14.10	1120
2	13.85	970
3	13.55	790
4	13.30	650
5	13.10	550
6	12.95	490
7	12.85	450
8	12.75	415
9	12.65	375
10	12.55	325
11	12.45	280
12	12.35	245
13	12.25	215
14	12.15	180
15	12.20	200
16	12.10	160
17	11.95	110
18	11.65	45
19	11.50	10
20	11.35	0
21	11.25	0
22	11.15	0
23	11.00	0
24	10.90	0
25	10.80	0
26	10.70	0
27	10.60	0
28	10.65	0
29	10.75	0
30	10.85	0
31	10.90	0

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.39
Sycamore	DeKalb	0.86
Aurora	Kane	—
Oswego	Kendall	0.75
Marengo	McHenry	0.77

Wisconsin

Station	County	Precip
Milwaukee		0.76
Manitowoc	Manitowoc	2.46
Hayward		5.02
Oshkosh	Winnebago	—
Delavan	Walworth	0.70
Fond du Lac	Fond du Lac	1.60

Total flow = 654 912 000 cu ft equiv. to a Rainfall of 0.45 in.

September 1889

Day	Gauge reading C.C.N.	Discharge cu ft per sec.	
1	10.90	0	Gauge readings as shown
2	10.80	0	were taken at 7 A.M.
3	10.70	0	
4	10.60	0	
5	10.60	0	
6	10.70	0	
7	10.80	0	
8	10.95	0	The total precipitation at
9	10.95	0	various points for this month
10	10.85	0	was as follows:—
11	10.80	0	Illinois
12	10.70	0	Station County Precipitation inches
13	10.70	0	Chicago Cook 2.75
14	10.60	0	Sycamore DeKalb 1.93
15	10.50	0	Aurora Kane —
16	10.50	0	Oswego Kendall 3.44
17	10.60	0	Marengo McHenry 1.68
18	10.70	0	
19	10.80	0	
20	10.90	0	
21	11.00	0	Wisconsin
22	11.10	0	Station County Precip.
23	11.25	0	Milwaukee 3.45
24	11.20	0	Manitowoc Manitowoc 2.51
25	11.20	0	Hayward 3.20
26	11.20	0	Oshkosh Winnebago —
27	11.30	0	Delavan Walworth 3.20
28	11.40	0	Fond du Lac Fond du Lac 4.79
29	11.40	0	
30	11.40	0	

Total flow = 0

October 1889

Day	Gauge reading C.C.N	Discharge cu ft per sec	
1	11.35	0	Gauge readings as shown
2	11.30	0	were taken at 7 A.M.
3	11.25	0	
4	11.25	0	
5	11.25	0	
6	11.20	0	
7	11.20	0	
8	11.25	0	The total precipitation
9	11.25	0	at various points for this
10	11.25	0	month was as follows.—
11	11.30	0	Illinois
12	11.35	0	Station County Precipitation inches
13	11.35	0	Chicago Cook 1.82
14	11.25	0	Sycamore DeKalb 0.85
15	11.25	0	Aurora Kane —
16	11.20	0	Oswego Kendall 1.00
17	11.15	0	Marengo McHenry 0.40
18	11.10	0	
19	11.05	0	
20	11.00	0	
21	10.90	0	Wisconsin
22	10.80	0	Station County Precip.
23	10.85	0	Milwaukee 0.56
24	10.95	0	Manitowoc Manitowoc 0.28
25	11.00	0	Hayward 0.36
26	11.10	0	Oshkosh Winnebago —
27	11.15	0	Delavan Walworth 0.14
28	11.20	0	Fond du Lac Fond du Lac 0.12
29	11.30	0	
30	11.35	0	
31	11.35	0	

Total flow = 0

November 1889

Day	Gauge Reading C.C.N.	Discharge cu ft per sec
1	11.35	0
2	11.35	0
3	11.35	0
4	11.35	0
5	11.35	0
6	11.35	0
7	11.35	0
8	11.35	0
9	11.45	5
10	11.45	5
11	11.40	0
12	11.35	0
13	11.35	0
14	11.30	0
15	11.30	0
16	11.30	0
17	11.35	0
18	11.35	0
19	11.30	0
20	11.20	0
21	11.10	0
22	11.00	0
23	10.95	0
24	10.85	0
25	10.75	0
26	10.75	0
27	10.85	0
28	10.95	0
29	10.95	0
30	11.00	0

Gauge readings as shown were taken at 7 AM

The total precipitation at various points for this month was as follows: —

Illinois

Station	County	Precipitation inches
Chicago	Cook	3.49
Sycamore	DeKalb	1.80
Aurora	Kane	—
Oswego	Kendall	2.83
Marengo	McHenry	2.34

Wisconsin

Station	County	Precip.
Milwaukee		2.71
Manitowoc	Manitowoc	2.77
Hayward		—
Oshkosh	Winnebago	0.31
Delavan	Walworth	1.69
Fond du Lac	Fond du Lac	2.07

Total flow = 8,640000 cu ft equiv. to a Rainfall of 0.006 in

December 1889

Day	Gauge reading C.C.N.	Discharge cu ft per sec	
1	11.10	0	Gauge readings as shown
2	11.20	0	were taken at 7 AM.
3	11.30	0	
4	11.40	0	
5	11.50	10	
6	11.60	30	
7	11.70	60	
8	11.75	70	The total precipitation at
9	11.70	60	various points for the
10	11.80	80	month was as follows:—
11	11.90	100	Illinois
12	12.00	120	Station — County — Precipitation inches
13	12.10	160	Chicago — Cook — 1.90
14	12.10	160	Sycamore — DeKalb — 1.52
15	12.10	160	Aurora — Kane — —
16	12.10	160	Oswego — Kendall — 1.91
17	12.20	200	Marengo — McHenry — 1.44
18	12.30	230	
19	12.40	260	
20	12.50	300	
21	12.60	350	Wisconsin
22	12.75	415	Station — County — Precip
23	12.80	430	Milwaukee — 2.87
24	12.90	470	Manitowoc — Manitowoc — 3.06
25	12.85	450	Hayward — —
26	12.80	430	Oshkosh — Winnebago — 4.83
27	12.75	415	Delavan — Walworth — 2.09
28	12.70	400	Fond du Lac — Fond du Lac — 2.33
29	12.70	400	
30	—	—	
31	—	—	

July 1890

Day	Gauge readings C.C.W.	Discharge cu. ft. per sec.	
1			Gauge readings as shown
2			were taken at 7 a.m.
3			No readings taken this year
4			previous to July 24
5			
6			
7			
8			The total precipitation at
9			various points for this
10			month was as follows:—
11			Illinois
12			Station — County — Precipitation inches
13			Chicago — Cook — 2.57
14			Oswego — Kendall — 1.19
15			Riley — McHenry — 0.53
16			Sycamore — DeKalb — 0.42
17			Winnebago — Winnebago — 0.40
18			Aurora — Kane — 0.78
19			Ft. Sheridan — Lake — 1.25
20			Ottawa — LaSalle — 0.34
21			
22			
23			Wisconsin
24	11.80	80	Station — County — Precip.
25	11.75	70	Milwaukee — — 1.77
26	11.72	64	Manitowoc — Manitowoc — 3.92
27	11.60	30	Hayward — — —
28	11.70	60	Oshkosh — Winnebago — 2.83
29	11.75	70	Delavan — Walworth — —
30	11.68	54	Fond du Lac — Fond du Lac — 2.33
31	11.45	5	Beloit — Rock — 0.28

August 1890

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	11.42	2	Gauge readings as shown		
2	11.38	0	were taken at 7 AM		
3	11.28	0			
4	11.35	0			
5	11.32	0			
6	11.65	45			
7	11.55	20			
8	11.48	8	The total precipitation at		
9	11.60	30	various points for this		
10	11.40	0	month was as follows:—		
11	11.50	10		Illinois	
12	11.48	8	Station	County	Precipitation inches
13	11.30	0	Chicago	Cook	4.58
14	11.30	0	Oswego	Kendall	2.65
15	11.25	0	Riley	McHenry	3.83
16	11.55	20	Sycamore	DeKalb	2.07
17	11.42	2	Winnebago	Winnebago	2.55
18	11.45	5	Aurora	Kane	2.77
19	11.45	5	Ft. Sheridan	Lake	2.47
20	11.45	5	Ottawa	LaSalle	2.72
21	11.48	8			
22	11.42	2			
23	11.58	26		Wisconsin	
24	11.35	0	Station	County	Precip.
25	11.38	0	Milwaukee		3.18
26	11.35	0	Manitowoc	Manitowoc	2.23
27	11.65	45	Hayward		—
28	11.60	30	Oshkosh	Winnebago	5.04
29	11.55	20	Delavan	Walworth	—
30	11.50	10	Fond du Lac	Fond du Lac	2.89
31	11.48	8	Beloit	Rock	3.98

Total flow = 26697600 cu ft equivalent to a Rainfall of 0.018 in

September 1890

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	11.52	14	Gauge readings as shown
2	11.48	8	were taken at 6:30 a.m.
3	11.55	20	
4	11.48	8	
5	11.48	8	
6	11.52	14	
7	11.50	10	
8	11.52	14	The total precipitation at
9	11.50	10	various points for this
10	11.52	14	month was as follows:—
11	11.42	2	Illinois
12	11.40	0	Station — County — Precipitation inches
13	11.42	2	Chicago — Cook — 1.39
14	11.38	0	Oswego — Kendall — 2.17
15	11.38	0	Riley — McHenry — 0.67
16	11.55	20	Sycamore — DeKalb — 1.22
17	11.65	45	Winnebago — Winnebago — 0.50
18	11.52	14	Aurora — Kane — 2.31
19	11.40	0	Ft. Sheridan — Lake — 1.32
20	11.35	0	Ottawa — La Salle — 2.48
21	11.40	0	
22	11.38	0	
23	11.40	0	Wisconsin
24	11.45	5	Station — County — Precip.
25	11.40	0	Milwaukee — — 0.65
26	11.38	0	Manitowoc — Manitowoc — 1.12
27	11.32	0	Hayward — — 3.45
28	11.32	0	Oshkosh — Winnebago — 1.54
29	11.38	0	Delavan — Walworth — —
30	11.32	0	Fond du Lac — Fond du Lac — 1.86
			Beloit — Rock — 0.61

Total flow = 17971200 cu ft equiv. to a rainfall of 0.012 in.

October 1890.

Day	Gauge reading C. C. N.	Discharge cu ft per sec
1	11.32	0
2	11.35	0
3	11.42	2
4	11.40	0
5	11.40	0
6	11.45	5
7	11.48	8
8	11.48	8
9	11.45	5
10	11.45	5
11	11.45	5
12	11.48	8
13	11.48	8
14	11.48	8
15	11.48	8
16	11.55	20
17	11.42	2
18	11.45	5
19	11.50	10
20	11.45	5
21	11.40	0
22	11.42	2
23	11.48	8
24	11.52	14
25	11.55	20
26	11.58	26
27	11.58	26
28	11.60	30
29	11.62	36
30	11.62	36
31	11.62	36

Gauge readings as shown were taken between 6 and 6:30 A.M.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	4.20
Oswego	Kendall	4.60
Riley	McHenry	5.38
Sycamore	DeKalb	13.48
Winnebago	Winnebago	6.46
Aurora	Kane	5.14
Ft. Sheridan	Lake	6.02
Ottawa	LaSalle	3.89

Wisconsin

Station	County	Precip.
Milwaukee	"	2.96
Manitowoc	Manitowoc	4.42
Hayward	"	2.56
Oshkosh	Winnebago	5.89
Delavan	Walworth	—
Fond du Lac	Fond du Lac	5.69
Beloit	Rock	4.56

Total flow = 29 894 400 cu ft equiv. to a Rainfall of 0.021 in.

November 1890

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	11.60	30	Gauge readings as shown
2	11.60	30	were taken between 6 & 7 A.M.
3	11.50	10	
4	11.48	8	
5	11.48	8	
6	11.45	5	
7	11.45	5	
8	11.48	8	The total precipitation at
9	11.48	8	various points for this
10	11.48	8	month was as follows:—
11	11.52	14	Illinois
12	11.52	14	Station — County — Precipitation inches
13	11.45	5	Chicago — Cook — 1.59
14	11.85	90	Oswego — Kendall — 1.89
15	11.40	0	Riley — McHenry — 1.74
16	11.50	10	Sycamore — DeKalb — 1.87
17	11.60	30	Winnebago — Winnebago — 2.10
18	11.60	30	Aurora — Kane — 2.08
19	11.60	30	Ft. Sheridan — Lake — 0.92
20	11.60	30	Ottawa — LaSalle — 2.06
21	11.60	30	
22	11.60	30	
23	11.62	36	Wisconsin
24	11.62	36	Station — County — Precip.
25	11.58	26	Milwaukee — 2.02
26	11.52	14	Manitowoc — Manitowoc — 1.81
27	11.50	10	Hayward — 0.90
28	11.60	30	Oshkosh — Winnebago — 2.18
29	11.52	14	Delavan — Walworth — 2.98
30	11.50	10	Fond du Lac — Fond du Lac — 1.99
			Beloit — Rock — 2.16

Total flow = 52,617,600 cu ft equiv. to a Rainfall of 0.036 in.

December 1890

Day	Gauge reading C.C.N.	Discharge cu ft per sec
1	11.50	10
2	11.52	14
3	11.55	20
4	11.60	30
5	11.60	30
6	11.60	30
7	11.60	30
8	11.60	30
9	11.70	60
10	11.65	45
11	11.60	30
12	11.55	20
13	11.50	10
14	11.48	8
15	11.48	8
16	11.68	54
17	11.55	20
18	11.50	10
19	11.40	0
20	11.55	20
21	11.40	0
22	11.40	0
23	11.55	20
24	11.55	20
25	11.50	10
26	11.40	0
27	11.40	0
28		—
29	—	—
30	—	—
31	—	—

Gauge readings as shown were taken at 7 AM.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.25
Oswego	Kendall	0.75
Riley	McHenry	1.13
Sycamore	DeKalb	1.50
Winnebago	Winnebago	1.40
Aurora	Kane	1.00
Ft Sheridan	Lake	2.27
Ottawa	LaSalle	0.27

Wisconsin

Station	County	Precip
Milwaukee		0.50
Manitowoc	Manitowoc	0.65
Hayward		0.28
Oshkosh	Winnebago	0.86
Delavan	Walworth	2.16
Fond du Lac	Fond du Lac	0.75
Beloit	Rock	0.55

May 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec.			
1			Gauge readings as shown		
2			were taken at 7 am.		
3	16.25	3100			
4	16.60	3550			
5	17.55	4920			
6	20.20	10120			
7	19.15	7800			
8	17.70	5150	The total precipitation		
9	16.90	3960	at various points for this		
10	15.90	2700	month was as follows:—		
11	15.20	2000		Illinois	
12	14.90	1740	Station	County	Precipitation inches
13	14.70	1570	Chicago	— Cook	6.77
14	14.70	1570	Winnebago	— Winnebago	8.33
15	14.70	1570	Riley	— McHenry	11.05
16	14.60	1500	Sycamore	— DeKalb	11.77
17	14.20	1200	Aurora	— Kane	8.29
18	13.70	880	Oswego	— Kendall	8.05
19	14.40	1350	Kankakee	— Kankakee	10.09
20	16.00	2810	Ottawa	— LaSalle	13.25
21	15.80	2590	Ft. Sheridan	— Lake	6.51
22	15.30	2100	Dixon	— Lee	8.93
23	14.85	1695	Streator	— LaSalle	—
24	14.50	1420	La Grange	— Cook	8.00
25	14.50	1420			
26	14.55	1460		Wisconsin	
27	14.20	1200	Station	County	Precip.
28	13.60	820	Sharon	Walworth	—
29	13.20	600	Waukesha	Waukesha	7.49
30	13.20	600	Milwaukee	Milwaukee	8.12
31	13.10	550	Beloit	Rock	7.65
			Delavan	Walworth	7.20
			Watertown	Jefferson	7.49

Total flow = 6216,048,000 cu ft equiv. to a Rainfall of 4.24 in.

June 1892

Day	Gauge reading C.C.D.	Discharge cuft per sec	
1	14.60	1500	Gauge readings as shown
2	14.95	1785	were taken at 7 AM.
3	15.10	1910	The highest reading recorded
4	15.05	1870	was 6 P.M. – 24th – 21.30 =
5	14.80	1650	discharge of 13000 cuft per sec.
6	14.55	1460	
7	14.50	1420	
8	16.30	3160	The total precipitation at
9	16.60	3550	various points for this
10	16.30	3160	month was as follows:—
11	15.50	2280	Illinois
12	14.90	1740	Station County Precipitation inches
13	14.60	1500	Chicago – Cook 10.58
14	16.00	2810	Winnebago - Winnebago 10.29
15	16.60	3550	Riley - McHenry 11.21
16	15.50	2280	Sycamore - DeKalb 11.23
17	14.90	1740	Aurora – Kane 13.09
18	15.00	1830	Oswego – Kendall 10.51
19	16.80	3820	Kankakee – Kankakee 4.67
20	18.30	6160	Ottawa – LaSalle 10.56
21	18.25	6080	Ft Sheridan – Lake 10.91
22	16.80	3820	Dixon – Lee 7.61
23	16.75	3755	La Grange – Cook 12.25
24	20.55	10960	
25	20.95	12000	Wisconsin
26	18.70	6700	Station County Precip.
27	17.10	4250	Waukesha Waukesha 8.53
28	15.70	2480	Manitowoc Manitowoc 7.71
29	14.90	1740	Oshkosh Winnebago 8.17
30	14.35	1315	Milwaukee Milwaukee 6.33
			Beloit Rock —
			Delavan Walworth 4.83
			Watertown Jefferson 8.76

Total flow = 8836,560 000 cuft equiv. to a Rainfall of 6.04 in.

July 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	13.90	1000
2	13.50	760
3	15.20	2000
4	15.40	2190
5	14.70	1570
6	14.00	1060
7	13.40	700
8	13.00	510
9	12.70	400
10	12.55	325
11	12.57	335
12	12.70	400
13	12.50	300
14	12.45	280
15	12.37	251
16	12.15	180
17	12.05	140
18	12.00	120
19	11.90	100
20	11.90	100
21	11.80	80
22	11.80	80
23	11.77	74
24	11.72	64
25	11.70	60
26	11.70	60
27	11.70	60
28	11.65	45
29	11.70	60
30	11.70	60
31	11.70	60

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.23
Winnebago	Winnebago	3.85
Riley	McHenry	4.78
Sycamore	DeKalb	2.56
Aurora	Kane	4.48
Oswego	Kendall	4.71
Kankakee	Kankakee	2.51
Ottawa	LaSalle	4.92
Ft. Sheridan	Lake	2.54
Dixon	Lee	3.84
LaGrange	Cook	—

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	1.60
Manitowoc	Manitowoc	3.03
Oshkosh	Winnebago	7.00
Milwaukee	Milwaukee	120
Delavan	Walworth	3.41
Watertown	Jefferson	1.21
Beaver Dam	Dodge	3.77

Total flow = 1159,833,000 cu ft equiv. to a Rainfall of 0.79 in.

August 1892

Day	Gauge reading. C. C. D.	Discharge cu ft per sec
1	11.70	60
2	11.70	60
3	11.65	45
4	11.60	30
5	11.57	24
6	11.60	30
7	11.52	14
8	11.55	20
9	11.55	20
10	11.55	20
11	11.55	20
12	11.50	10
13	11.47	7
14	11.45	5
15	11.42	2
16	11.42	2
17	11.42	2
18	11.40	0
19	11.40	0
20	11.40	0
21	11.40	0
22	11.40	0
23	11.40	0
24	11.40	0
25	11.47	7
26	11.47	7
27	11.47	7
28	11.47	7
29	11.50	10
30	11.50	10
31	11.50	10

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.85
Winnebago	Winnebago	—
Riley	McHenry	4.42
Sycamore	DeKalb	3.56
Aurora	Kane	2.74
Oswego	Kendall	1.71
Kankakee	Kankakee	—
Ottawa	LaSalle	0.81
Ft. Sheridan	Lake	0.86
Dixon	Lee	1.94
LaGrange	Cook	—

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	3.07
Manitowoc	Manitowoc	4.30
Oshkosh	Winnebago	1.90
Milwaukee	Milwaukee	3.47
Delavan	Walworth	3.35
Watertown	Jefferson	2.26
Beaver Dam	Dodge	3.09

Total flow = 37,065 600 cu ft equiv. to a Rainfall of 0.025 in.

September 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	11.50	10	Gauge readings as shown		
2	11.45	5	were taken 7 A.M.		
3	11.40	0			
4	11.40	0			
5	11.40	0			
6	11.40	0			
7	11.40	0			
8	11.40	0	The total precipitation		
9	11.40	0	at various points for this		
10	11.40	0	month was as follows:—		
11	11.55	20	Illinois		
12	11.65	45	Station	County	Precipitation inches
13	11.70	60	Chicago	Cook	1.34
14	11.65	45	Winnebago	Winnebago	—
15	11.60	30	Riley	McHenry	1.43
16	11.50	10	Sycamore	DeKalb	1.62
17	11.50	10	Aurora	Kane	2.53
18	11.50	10	Oswego	Kendall	2.32
19	11.45	5	Kankakee	Kankakee	2.03
20	11.45	5	Ottawa	LaSalle	2.56
21	11.40	0	Ft. Sheridan	Lake	1.67
22	11.40	0	Dixon	Lee	2.56
23	11.40	0	LaGrange	Cook	1.70
24	11.40	0			
25	11.40	0	Wisconsin		
26	11.40	0	Station	County	Precip.
27	11.40	0	Waukesha	Waukesha	2.45
28	11.40	0	Manitowoc	Manitowoc	1.74
29	11.40	0	Oshkosh	Winnebago	1.61
30	11.40	0	Milwaukee	Milwaukee	2.21
31	11.40	0	Delavan	Walworth	1.97
			Sharon	Walworth	1.53
			Watertown	Jefferson	3.85

Total flow = 22 032 000 cu ft equiv. to a Rainfall of 0.015 in.

October 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	11.40	0	Gauge readings as shown		
2	11.40	0	were taken at 7 am.		
3	11.40	0			
4	11.40	0			
5	11.40	0			
6	11.40	0			
7	11.40	0			
8	11.40	0	The total precipitation		
9	11.40	0	at various points for the		
10	11.40	0	month was as follows:—		
11	11.40	0		Illinois	
12	11.40	0	Station	County	Precipitation inches
13	11.40	0	Chicago	Cook	6.54
14	11.40	0	Winnebago	Winnebago	—
15	11.40	0	Riley	McHenry	0.72
16	11.40	0	Sycamore	DeKalb	0.95
17	11.40	0	Aurora	Kane	1.23
18	11.40	0	Oswego	Kendall	0.96
19	11.40	0	Galva	Henry	—
20	11.40	0	Kankakee	Kankakee	0.86
21	11.40	0	Ottawa	LaSalle	0.63
22	11.40	0	Ft. Sheridan	Lake	—
23	11.40	0	Dixon	Lee	1.07
24	11.40	0	LaGrange	Cook	0.81
25	11.45	5		Wisconsin	
26	11.45	5	Station	County	Precip.
27	11.50	10	Waukesha	Waukesha	0.78
28	11.50	10	Oconomowoc	Waukesha	1.27
29	11.50	10	Oshkosh	Winnebago	1.22
30	11.50	10	Milwaukee	Milwaukee	1.66
31	11.45	5	Delavan	Walworth	0.84
			Sharon	Walworth	0.88
			Watertown	Jefferson	0.52

Total flow = 4,752,000 cu ft equiv. to a Rainfall of 0.0035 in.

November 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	11.45	5
2	11.45	5
3	11.45	5
4	11.45	5
5	11.45	5
6	11.45	5
7	11.45	5
8	11.50	10
9	11.50	10
10	11.50	10
11	11.50	10
12	11.50	10
13	11.50	10
14	11.50	10
15	11.55	20
16	11.55	20
17	11.55	20
18	11.60	30
19	11.60	30
20	11.60	30
21	11.60	30
22	11.55	20
23	11.50	10
24	11.50	10
25	11.50	10
26	11.47	7
27	11.45	5
28	11.42	2
29	11.45	5
30	11.50	10

Gauge readings as shown were taken at 7 A.M.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.68
Winnebago	Winnebago	2.12
Riley	McHenry	1.64
Sycamore	DeKalb	2.13
Aurora	Kane	2.07
Oswego	Kendall	2.11
Galva	Henry	1.27
Kankakee	Kankakee	2.46
Ottawa	LaSalle	2.48
Ft. Sheridan	Lake	1.78
Dixon	Lee	1.67
LaGrange	Cook	2.24

Wisconsin

Station	County	Precipitation inches
Waukesha	Waukesha	1.49
Oconomowoc	Waukesha	2.42
Delavan	Walworth	1.60
Milwaukee	Milwaukee	1.84
Sharon	Walworth	1.91
Watertown	Jefferson	1.52

Total flow = 31449600 cu ft equiv. to a Rainfall of 0.021 in.

December 1892

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	11.50	10	Gauge readings as shown		
2	11.50	10	were taken at 7 AM.		
3	11.50	10			
4	11.50	10			
5	11.50	10			
6	11.52	14			
7	11.57	24			
8	11.62	36	The total precipitation		
9	11.65	45	at various points for this		
10	11.65	45	month was as follows:—		
11	11.60	30		Illinois	
12	11.55	20	Station	County	Precipitation inches
13	11.55	20	Chicago	Cook	1.63
14	11.60	30	Winnebago	Winnebago	2.38
15	11.60	30	Riley	McHenry	1.71
16	11.60	30	Sycamore	DeKalb	2.06
17	11.60	30	Aurora	Kane	2.54
18	11.70	60	Oswego	Kendall	1.97
19	11.75	70	Galva	Henry	1.62
20	11.70	60	Kankakee	Kankakee	—
21	11.60	30	Ottawa	LaSalle	1.84
22	11.52	12	Ft Sheridan	Lake	2.60
23	11.50	10	Dixon	Lee	2.56
24	11.47	7	LaGrange	Cook	1.93
25	11.47	7			
26	11.47	7		Wisconsin	
27	11.45	5	Station	County	Precip.
28	11.42	2	Waukesha	Waukesha	1.60
29	11.40	0	Oconomowoc	Waukesha	2.26
30	11.40	0	Milwaukee	Milwaukee	1.61
31	11.40	0	Sharon	Walworth	2.30
			Delavan	Walworth	1.16
			Watertown	Jefferson	2.00

Total flow = 58,233,600 cu ft equiv. to a Rainfall of 0.040 in

January 1893

Day	Gauge reading C. G. W.	Discharge cu ft per sec			
1	11.40	0	Gauge readings as shown		
2	11.40	0	were taken at 7 A.M.		
3	11.40	0			
4	11.40	0			
5	11.40	0			
6	11.40	0			
7	11.40	0			
8	11.40	0	The total precipitation at		
9	11.40	0	various points for the		
10	11.40	0	month was as follows:—		
11	11.42	2		Illinois	
12	11.45	5	Station	County	Precipitation inches
13	11.45	5	Chicago	Cook	2.08
14	11.47	7	Winnebago	Winnebago	2.04
15	11.47	7	Riley	McHenry	1.57
16	11.50	10	Sycamore	DeKalb	1.83
17	11.50	10	Aurora	Kane	2.37
18	11.50	10	Oswego	Kendall	1.85
19	11.50	10	Galva	Henry	0.95
20	11.50	10	Kankakee	Kankakee	1.00
21	11.50	10	Ottawa	LaSalle	2.20
22	11.50	10	Ft. Sheridan	Lake	2.02
23	11.50	10	Dixon	Lee	2.07
24	11.50	10	La Grange	Cook	1.91
25	11.47	7			
26	11.47	7		Wisconsin	
27	11.45	5	Station	County	Precip.
28	11.40	0	Waukesha	Waukesha	1.42
29	11.40	0	Oconomowoc	Waukesha	1.75
30	11.40	0	Milwaukee	Milwaukee	1.80
31	11.47	7	Sharon	Walworth	1.71
			Delavan	Walworth	1.26
			Watertown	Jefferson	1.62

Total flow = 12,268,800 cu ft equiv. to a Rainfall of 0.0084 in.

February 1893

Day	Gauge reading C.C.W.	Discharge cu ft per sec
1	11.47	7
2	11.47	7
3	11.47	7
4	11.47	7
5	11.50	10
6	11.50	10
7	11.55	20
8	11.55	20
9	11.55	20
10	11.55	20
11	11.55	20
12	11.60	30
13	11.65	45
14	11.70	60
15	12.10	160
16	13.10	550
17	13.40	700
18	13.60	820
19	12.90	470
20	12.50	300
21	12.25	215
22	12.20	200
23	12.10	160
24	12.00	120
25	11.85	90
26	11.90	100
27	11.80	80
28	13.90	1000

Gauge readings as shown were taken at 7 am.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.44
Winnebago	Winnebago	2.04
Riley	McHenry	1.55
Sycamore	DeKalb	2.12
Aurora	Kane	3.21
Oswego	Kendall	3.16
Galva	Henry	1.65
Kankakee	Kankakee	0.38
Ottawa	La Salle	3.03
Ft Sheridan	Lake	1.10
Dixon	Lee	1.94
La Grange	Cook	—

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	1.21
Oconomowoc	Waukesha	0.93
Milwaukee	Milwaukee	1.51
Sharon	Walworth	1.94
Delavan	Walworth	0.66
Watertown	Jefferson	1.68

Total flow = 453,427,200 cu ft equiv. to a Rainfall of 0.31 in.

March 1893

Day	Gauge Reading C.W.	Discharge cub ft per sec.
1	16.10	2920
2	16.25	3100
3	17.65	5075
4	18.80	7100
5	17.45	4765
6	16.10	2920
7	15.50	2280
8	15.60	2370
9	18.50	6520
10	18.40	6340
11	18.20	6000
12	18.20	6000
13	17.60	5000
14	16.60	3550
15	15.80	2590
16	14.60	1500
17	14.10	1120
18	13.85	970
19	13.60	820
20	13.32	660
21	13.22	610
22	13.45	730
23	14.45	1385
24	15.30	2100
25	15.60	2370
26	15.30	2100
27	14.90	1740
28	14.70	1570
29	14.30	1280
30	14.00	1060
31	13.60	820

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.69
Winnebago	Winnebago	2.30
Riley	McHenry	1.82
Sycamore	DeKalb	2.22
Aurora	Kane	3.39
Oswego	Kendall	2.68
Galva	Henry	2.88
Kankakee	Kankakee	1.13
Ottawa	La Salle	3.30
Ft. Sheridan	Lake	1.95
Dixon	Lee	2.83
LaGrange	Cook	2.15

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	2.95
Oconomowoc	Waukesha	1.77
Milwaukee	Milwaukee	3.29
Sharon	Walworth	2.39
Delavan	Walworth	2.31
Watertown	Jefferson	2.58

Total flow = 7548,336,000 cu ft equiv. to a Rainfall of 5.15 in.

April 1893

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	13.20	600	Gauge readings as shown were
2	12.80	430	taken at 7 a.m.
3	12.60	350	
4	12.45	280	
5	12.40	260	
6	12.35	245	
7	12.20	200	
8	12.10	160	The total precipitation
9	12.12	168	at various points for this
10	12.10	160	month was as follows:—
11	12.10	160	Illinois
12	12.15	180	Station County Precipitation inches
13	12.50	300	Chicago Cook 4.16
14	12.75	415	Winnebago Winnebago 4.66
15	12.55	325	Riley McHenry 3.71
16	12.40	260	Sycamore DeKalb 4.59
17	12.32	236	Aurora Kane 5.81
18	12.30	230	Oswego Kendall 4.80
19	12.35	245	Galva Henry 5.73
20	13.60	820	Kankakee Kankakee 5.45
21	16.40	3280	Ottawa LaSalle 5.23
22	16.60	3550	Ft. Sheridan Lake 5.87
23	16.17	3004	Dixon Lee 4.02
24	15.70	2480	LaGrange Cook 5.61
25	15.35	2145	Streator LaSalle 6.17
26	14.90	1740	
27	15.75	2535	Wisconsin
28	15.50	2280	Station County Precip
29	14.90	1740	Waukesha Waukesha 5.64
30	14.70	1570	Milwaukee Milwaukee 5.69
			Oconomowoc Waukesha 5.85
			Sharon Walworth 5.99
			Delavan Walworth 4.79

Total flow = 2622,067,200 cu ft equiv to a Rainfall of 1.79 in.

May 1893.

Day	Gauge reading C.C.H.	Discharge cu ft per sec.	
1	15.60	2370	Gauge readings as shown
2	15.85	2645	were taken at 7 AM
3	15.40	2190	
4	14.70	1570	
5	14.20	1200	
6	14.20	1200	
7	14.10	1120	
8	13.80	940	The total precipitation
9	13.40	700	at various points for the
10	13.10	550	month was as follows:—
11	12.80	430	Illinois
12	12.77	421	Station · County · Precipitation inches
13	13.10	550	Chicago · Cook · 1.93
14	13.00	510	Winnebago · Winnebago · —
15	13.02	518	Riley · McHenry · 2.99
16	13.12	560	Sycamore · DeKalb · 3.25
17	13.25	625	Aurora · Kane · 2.72
18	13.20	600	Oswego · Kendall · 2.59
19	13.10	550	Galva · Henry · 2.45
20	12.85	450	Kankakee · Kankakee · 4.83
21	12.65	375	Ottawa · LaSalle · 1.95
22	12.52	310	Ft. Sheridan · Lake · 2.07
23	12.35	245	Dixon · Lee · 2.94
24	12.35	245	LaGrange · Cook · 2.27
25	12.35	245	Streator · LaSalle · 3.21
26	12.30	230	
27	12.20	200	Wisconsin
28	12.20	200	Station · County · Precip.
29	12.15	180	Waukesha · Waukesha · 2.11
30	12.10	160	Milwaukee · Milwaukee · 1.79
31	12.00	120	Oconomowoc · Waukesha · 1.72
			Sharon · Walworth · 1.69
			Delavan · Walworth · 1.66

Total flow = 1918,857,600 cu ft equiv. to a Rainfall of 1.31 in.

June 1893

Day	Gauge reading CCD	Discharge cuft per sec
1	12.00	120
2	12.00	120
3	12.30	230
4	12.80	430
5	13.85	970
6	13.15	575
7	12.80	430
8	12.52	310
9	12.40	260
10	12.50	300
11	15.25	2050
12	15.90	2700
13	15.10	1910
14	14.20	1200
15	13.70	880
16	13.32	660
17	13.10	550
18	12.80	430
19	12.55	325
20	12.50	300
21	13.90	1000
22	15.60	2370
23	14.75	1610
24	13.90	1000
25	13.30	650
26	13.00	510
27	12.80	430
28	12.60	350
29	12.40	260
30	12.25	215

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for the month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	3.59
Winnebago	Winnebago	3.26
Riley	McHenry	5.13
Sycamore	DeKalb	5.04
Aurora	Kane	3.64
Oswego	Kendall	3.27
Galva	Henry	1.37
Kankakee	Kankakee	1.28
Ottawa	LaSalle	2.49
Ft. Sheridan	Lake	3.62
Dixon	Lee	4.42
LaGrange	Cook	5.30
Streator	LaSalle	0.96

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	4.32
Milwaukee		5.46
Oconomowoc	Waukesha	4.46
Sharon	Walworth	4.22
Delavan	Walworth	5.03

Total flow = 1999,728 000 cu.ft. equiv to a Rainfall of 1.37 in.

July 1893.

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	12.10	160
2	12.00	120
3	11.95	110
4	11.90	100
5	11.82	84
6	11.80	80
7	11.75	70
8	11.80	80
9	11.90	100
10	12.15	180
11	12.15	180
12	12.00	120
13	11.95	110
14	11.92	104
15	11.87	94
16	11.85	90
17	11.80	80
18	11.80	80
19	11.75	70
20	11.72	64
21	11.70	60
22	11.65	45
23	11.60	30
24	11.60	30
25	11.57	24
26	11.57	24
27	11.57	24
28	11.55	20
29	11.52	14
30	11.52	14
31	11.52	14

Gauge readings as shown were taken at 7 Am.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	3.08
Winnebago	Winnebago	2.61
Riley	McHenry	2.32
Sycamore	DeKalb	3.65
Aurora	Kane	1.19
Oswego	Kendall	1.99
Galva	Henry	1.08
Kankakee	Kankakee	Trace
Ottawa	LaSalle	1.02
Ft. Sheridan	Lake	3.77
Dixon	Lee	3.74
LaGrange	Cook	2.96

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	3.05
Oconomowoc	Waukesha	3.53
Milwaukee	Milwaukee	3.67
Sharon	Walworth	3.02
Delavan	Walworth	3.49
Watertown	Jefferson	3.07

Total flow = 205,200000 cu ft equiv. to a Rainfall of 0.14 in.

August 1893

Day	Gauge Reading C.C.D.	Discharge cu ft per sec.			
1	11.50	10	Gauge readings as shown		
2	11.45	5	were taken at 7 A.M.		
3	11.45	5			
4	11.42	2			
5	11.40	0			
6	11.37	0			
7	11.35	0			
8	11.32	0	The total precipitation at		
9	11.30	0	various points for this		
10	11.22	0	month was as follows:—		
11	11.20	0		Illinois	
12	11.20	0	Station	County	Precipitation inches
13	11.20	0	Chicago	Cook	0.18
14	11.20	0	Winnebago	Winnebago	0.80
15	11.20	0	Riley	McHenry	0.45
16	11.25	0	Sycamore	DeKalb	0.46
17	11.30	0	Aurora	Kane	0.32
18	11.32	0	Oswego	Kendall	0.22
19	11.32	0	Galva	Henry	0.69
20	11.30	0	Kankakee	Kankakee	0.55
21	11.30	0	Ottawa	LaSalle	0.77
22	11.27	0	Ft. Sheridan	Lake	0.10
23	11.27	0	Dixon	Lee	0.39
24	11.25	0	LaGrange	Cook	0.23
25	11.22	0			
26	11.22	0		Wisconsin	
27	11.25	0	Station	County	Precip.
28	11.30	0	Waukesha	Waukesha	1.32
29	11.27	0	Oconomowoc	Waukesha	1.28
30	11.25	0	Milwaukee	Milwaukee	1.01
31	11.20	0	Sharon	Walworth	1.20
			Delavan	Walworth	1.43
			Watertown	Jefferson	1.55

Total flow = 1900 800 cuft equiv. to a Rainfall of 0.0013 in

September 1893

Day	Gauge reading G.C.D.	Discharge cu.ft. per sec.	
1	11.20	0	Gauge readings as shown
2	11.20	0	were taken at 7 a.m.
3	11.20	0	
4	11.20	0	
5	11.20	0	
6	11.20	0	
7	11.20	0	
8	11.20	0	The total precipitation
9	11.20	0	at various points for this
10	11.20	0	month was as follows:—
11	11.20	0	Illinois
12	11.20	0	Station — County — Precipitation inches
13	11.20	0	Chicago — Cook — 1.98
14	11.20	0	Winnebago — Winnebago — 2.68
15	11.20	0	Riley — McHenry — 4.18
16	11.20	0	Sycamore — DeKalb — 3.83
17	11.20	0	Aurora — Kane — 2.70
18	11.17	0	Oswego — Kendall — 2.88
19	11.17	0	Galva — Henry — 3.57
20	11.17	0	Kankakee — Kankakee — 1.69
21	11.17	0	Ottawa — LaSalle — 2.29
22	11.30	0	Ft. Sheridan — Lake — 3.62
23	11.35	0	Dixon — Lee — 3.22
24	11.35	0	LaGrange — Cook — 2.84
25	11.35	0	Streator — LaSalle — 3.00
26	11.30	0	
27	11.30	0	Wisconsin
28	11.35	0	Station — County — Precip.
29	11.35	0	Waukesha — Waukesha — 2.87
30	11.40	0	Milwaukee — Milwaukee — 3.24
			Oconomowoc — Waukesha — 2.94
			Sharon — Walworth — 2.66
			Delavan — Walworth — 2.60

Total flow = 0.

October 1893

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1	11.35	0	Gauge readings as shown
2	11.35	0	were taken at 7 A.M.
3	11.95	110	
4	11.70	60	
5	11.57	24	
6	11.50	10	
7	11.50	10	
8	11.50	10	The total precipitation
9	11.50	10	at various points for this
10	11.60	30	month was as follows:—
11	11.50	10	Illinois
12	11.45	5	Station — County — Precipitation inches
13	11.45	5	Chicago — Cook — 1.75
14	11.45	5	Winnebago — Winnebago — 2.45
15	11.45	5	Riley — McHenry — 2.47
16	11.45	5	Sycamore — DeKalb — 1.13
17	11.35	0	Aurora — Kane — 3.20
18	11.32	0	Oswego — Kendall — 2.28
19	11.40	0	Galva — Henry — 0.46
20	11.40	0	Kankakee — Kankakee — 1.70
21	11.40	0	Ottawa — LaSalle — 1.10
22	11.27	0	Ft. Sheridan — Lake — 1.19
23	11.27	0	Dixon — Lee — 1.05
24	11.27	0	LaGrange — Cook — 0.52
25	11.27	0	
26	11.27	0	Wisconsin
27	11.27	0	Station — County — Precip.
28	11.30	0	Waukesha — Waukesha — 2.41
29	11.27	0	Oconomowoc — Waukesha — 2.45
30	11.32	0	Milwaukee — Milwaukee — 1.62
31	11.35	0	Sharon — Walworth — 3.90
			Delavan — Walworth — 2.68

Total flow = 25,833 600 cu ft equiv to a Rainfall of 0.0176 in

November 1893

Day	Gauge reading CCD.	Discharge cuft per sec.	
1	11.27	0	Gauge readings as shown
2	11.30	0	were taken at 7 am.
3	11.50	10	
4	11.35	0	
5	11.35	0	
6	11.30	0	
7	11.30	0	
8	11.30	0	The total precipitation for
9	11.35	0	this month, at various
10	11.50	10	points was as follows:—
11	11.40	0	Illinois
12	11.35	0	Station / County / Precipitation inches
13	11.30	0	Chicago / Cook / 2.45
14	11.30	0	Winnebago / Winnebago / 1.67
15	11.40	0	Riley / McHenry / 2.34
16	11.30	0	Sycamore / DeKalb / 2.74
17	11.30	0	Aurora / Kane / 2.99
18	11.30	0	Oswego / Kendall / 2.25
19	11.30	0	Galva / Henry / 2.25
20	11.30	0	Kankakee / Kankakee / —
21	11.30	0	Ottawa / LaSalle / 2.18
22	11.30	0	Ft. Sheridan / Lake / 2.87
23	11.30	0	Dixon / Lee / 2.13
24	11.30	0	LaGrange / Cook / 2.26
25	11.30	0	Streator / LaSalle / 2.80
26	11.30	0	Braidwood / Will / 1.87
27	11.35	0	
28	11.30	0	Wisconsin
29	11.30	0	Waukesha / Waukesha / 1.74
30	11.30	0	Milwaukee / Milwaukee / 1.20
			Oconomowoc / Waukesha / 1.24
			Sharon / Walworth / 2.35
			Delavan / Walworth / 1.17

Total flow = 1728 000 cuft equiv. to a Rainfall of 0.0012 in

December 1893

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	11.30	0
2	11.30	0
3	11.30	0
4	11.30	0
5	11.40	0
6	11.40	0
7	11.40	0
8	11.40	0
9	11.30	0
10	11.30	0
11	11.30	0
12	11.30	0
13	11.35	0
14	11.48	8
15	11.50	10
16	11.60	30
17	12.05	140
18	12.20	200
19	12.70	400
20	12.40	260
21	12.20	200
22	12.00	120
23	11.95	110
24	12.15	180
25	12.82	440
26	13.10	550
27	12.95	490
28	12.65	375
29	12.60	350
30	12.40	260
31	12.65	375

Gauge readings as shown were taken at 7 AM

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.14
Winnebago	Winnebago	1.29
Riley	McHenry	1.42
Sycamore	DeKalb	2.19
Aurora	Kane	2.60
Oswego	Kendall	1.85
Galva	Henry	1.54
Kankakee	Kankakee	—
Ottawa	LaSalle	2.16
Ft. Sheridan	Lake	1.61
Dixon	Lee	1.69
LaGrange	Cook	2.00
Streator	LaSalle	0.97
Braidwood	Will	1.57

Wisconsin

Station	County	Precip
Milwaukee	Milwaukee	2.59
Waukesha	Waukesha	2.61
Sharon	Walworth	1.82
Delavan	Walworth	0.84

Total flow = 388,627,200 cu ft equiv. to a Rainfall of 0.265 in.

January 1894

Day	Gauge reading C.C.W.	Discharge cu ft per sec			
1	12.40	260	Gauge readings as shown		
2	12.17	180	were taken at 7 AM.		
3	12.10	160			
4	12.07	140			
5	12.05	140			
6	11.90	100			
7	11.90	100			
8	11.87	90	The total precipitation at		
9	11.80	80	various points for this month		
10	11.80	80	was as follows—		
11	11.75	70	Illinois		
12	11.90	100	Station	County	Precipitation inches
13	11.70	60	Chicago	Cook	1.55
14	11.65	45	Aurora	Kane	2.76
15	11.62	35	Braidwood	Will	1.16
16	11.65	45	Chemung	McHenry	2.25
17	11.67	50	Dixon	Lee	2.15
18	11.70	60	Ft Sheridan	Lake	2.94
19	11.65	45	Galva	Henry	0.64
20	11.70	60	Kankakee	Kankakee	2.35
21	13.90	1000	LaGrange	Cook	1.64
22	14.45	1385	Ottawa	LaSalle	2.38
23	13.50	760	Riley	McHenry	2.24
24	13.40	700	Sycamore	DeKalb	2.50
25	12.90	470	Winnebago	Winnebago	1.48
26	12.70	400	Oswego	Kendall	2.31
27	12.80	430	Streator	LaSalle	1.90
28	12.80	430	Wisconsin		
29	12.70	400	Station	County	Precip.
30	12.55	325	Milwaukee	Milwaukee	1.64
31	12.45	280	Waukesha	Waukesha	1.34
			Sharon	Walworth	1.97
			Delavan	Walworth	1.09

Total flow = 732 672 000 cu ft equiv. to a Rainfall of 0.50 in.

February 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	12.35	245	Gauge readings as shown
2	12.30	230	were taken at 7 a.m.
3	12.30	230	
4	12.20	200	
5	12.10	160	
6	12.15	180	
7	12.02	125	
8	11.97	120	The total precipitation at
9	12.20	120	various points for this month
10	14.60	1500	was as follows:—
11	15.60	2370	Illinois
12	15.20	2000	Station — County — Precipitation inches
13	14.82	1670	Chicago — Cook — 2.13
14	14.50	1420	Aurora — Kane — 1.95
15	13.66	855	Braidwood — Will — 1.31
16	13.18	585	Chemung — McHenry — 1.33
17	13.16	580	Dixon — Lee — 1.97
18	12.86	455	Ft. Sheridan — Lake — 1.45
19	12.96	495	Galva — Henry — 0.88
20	13.18	585	Kankakee — Kankakee — 1.67
21	13.18	585	La Grange — Cook — 1.72
22	13.18	585	Ottawa — La Salle — 1.58
23	13.13	565	Riley — McHenry — 1.33
24	12.91	475	Sycamore — DeKalb — 1.35
25	12.76	420	Winnebago — Winnebago — 1.25
26	12.66	375	Oswego — Kendall — 1.10
27	12.56	325	Streator — La Salle — 3.44
28	13.06	530	Wisconsin
			Station — County — Precip.
			Milwaukee — Milwaukee — 1.63
			Waukesha — Waukesha — 0.81
			Sharon — Walworth — 1.95
			Delavan — Walworth — 0.46

Total flow = 1553 904 000 cu ft equiv. to a Rainfall of 1.06 in.

March 1894

Day	Gauge Reading C.C.D.	Discharge cu ft per sec			
1	13.06	530	Gauge readings as shown were		
2	14.56	1460	taken at 7 A.M.		
3	15.16	1960	The highest gauge reading noted		
4	15.56	2330	was 6 P.M.-6 - 18.76 = discharge		
5	16.56	3490	of 7000 cu ft per sec.		
6	18.26	6080			
7	18.73	6960			
8	18.41	6340	The total precipitation at		
9	17.68	5120	various points for this month		
10	16.96	4040	was as follows:—		
11	16.06	2870		Illinois	
12	15.06	1870	Station	County	Precipitation inches
13	14.41	1350	Chicago	Cook	2.66
14	13.91	1000	Aurora	Kane	3.17
15	13.56	790	Braidwood	Will	2.87
16	13.46	740	Chemung	McHenry	2.75
17	13.26	630	Dixon	Lee	3.12
18	12.96	490	Ft. Sheridan	Lake	2.07
19	12.91	470	Galva	Henry	2.53
20	12.81	430	Kankakee	Kankakee	2.04
21	12.78	420	LaGrange	Cook	—
22	12.86	450	Ottawa	LaSalle	2.57
23	12.81	430	Riley	McHenry	3.02
24	12.71	400	Sycamore	DeKalb	3.26
25	12.51	300	Winnebago	Winnebago	3.55
26	12.21	200	Oswego	Kendall	2.68
27	11.93	105	Streator	LaSalle	2.95
28	11.81	80		Wisconsin	
29	12.01	120	Station	County	Precip.
30	12.06	130	Milwaukee	Milwaukee	2.53
31	11.96	110	Waukesha	Waukesha	2.49
			Sharon	Walworth	3.31
			Delavan	Walworth	2.70

Total flow = 4466,448,000 cu ft equiv. to a Rainfall of 3.05"

April 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	11.81	80	Gauge readings as shown
2	13.16	575	were taken between 6 & 7 A.M.
3	12.96	490	
4	12.83	440	
5	12.66	375	
6	12.51	300	
7	12.36	250	
8	12.26	220	The total precipitation at
9	12.21	200	various points for this month
10	12.31	230	was as follows:—
11	14.41	1350	Illinois
12	14.56	1460	Station — County — Precipitation inches
13	14.01	1060	Chicago — Cook — 2.65
14	13.56	790	Aurora — Kane — 2.49
15	13.31	650	Braidwood — Will — 2.23
16	13.13	570	Chemung — McHenry — 3.34
17	12.91	470	Dixon — Lee — 2.04
18	12.68	380	Ft. Sheridan — Lake — 4.07
19	12.86	450	Galva — Henry — 1.21
20	12.86	450	Kankakee — Kankakee — 3.54
21	12.76	420	La Grange — Cook — —
22	12.43	275	Ottawa — La Salle — 1.51
23	12.36	250	Riley — McHenry — 2.62
24	12.26	220	Sycamore — DeKalb — 2.87
25	12.21	200	Winnebago — Winnebago — 2.74
26	12.06	140	Oswego — Kendall — 2.82
27	12.01	120	Streator — La Salle — 1.93
28	11.96	110	Wisconsin
29	12.06	140	Station — County — Precip.
30	12.33	235	Milwaukee — Milwaukee — 2.89
			Waukesha — Waukesha — 2.94
			Sharon — Walworth — 3.73
			Delavan — Walworth — 3.79

Total flow = 1114560000 cu ft equiv. to a Rainfall of 0.96 in

May 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec.	
1	12.66	375	Gauge readings as shown
2	13.73	900	were taken at 6:15 A.M.
3	13.86	970	The highest reading noted was
4	13.83	960	6:20 P.M.–7th–16.56–discharge
5	14.41	1350	of 3490 cu ft per sec.
6	15.48	2250	
7	16.31	3160	
8	16.26	3080	The total precipitation at
9	15.48	2250	various points for this month
10	14.86	1700	was as follows:—
11	14.48	1400	Illinois.
12	14.08	1100	Station — County — Precipitation inches
13	13.48	750	Chicago — Cook — 3.35
14	13.13	570	Aurora — Kane — 2.76
15	12.66	375	Braidwood — Will — 3.69
16	12.81	430	Chemung — McHenry — 3.02
17	12.81	430	Dixon — Lee — 4.28
18	12.63	360	Ft. Sheridan — Lake — 4.01
19	14.21	1200	Galva — Henry — 2.18
20	14.93	1780	Kankakee — Kankakee — 3.29
21	15.11	1910	La Grange — Cook — 3.16
22	14.41	1350	Ottawa — La Salle — 4.01
23	13.76	920	Riley — McHenry — 3.62
24	13.31	659	Sycamore — De Kalb — 3.90
25	13.03	525	Winnebago — Winnebago — 3.51
26	12.73	410	Oswego — Kendall — 2.82
27	12.46	280	Streator — La Salle — 3.62
28	12.36	240	Wisconsin
29	12.31	230	Station — County — Precip.
30	12.16	180	Milwaukee — Milwaukee — 4.66
31	12.08	160	Waukesha — Waukesha — 3.68
			Sharon — Walworth — 4.53
			Delavan — Walworth — 3.86

Total flow = 2785968000 cu ft equiv to a Rainfall of 1.90 in.

June 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	12.08	160	Gauge readings as shown		
2	11.96	110	were taken at 6:15 a.m.		
3	11.91	100			
4	11.76	70			
5	11.81	80			
6	11.76	70			
7	11.66	50			
8	11.66	50	The total precipitation		
9	11.66	50	at various points for the		
10	11.66	50	month was as follows:—		
11	11.63	40	Illinois		
12	11.58	26	Station	County	Precipitation inches
13	11.56	22	Chicago	Cook	1.96
14	11.56	22	Aurora	Kane	1.87
15	11.56	22	Braidwood	Will	2.84
16	11.53	16	Chemung	McHenry	3.56
17	11.49	9	Dixon	Lee	1.91
18	11.61	32	Ft. Sheridan	Lake	0.51
19	11.61	32	Galva	Henry	4.14
20	11.56	22	Kankakee	Kankakee	1.11
21	11.61	32	LaGrange	Cook	2.09
22	11.61	32	Ottawa	LaSalle	3.03
23	11.56	22	Riley	McHenry	1.22
24	11.56	22	Sycamore	DeKalb	1.79
25	11.53	16	Winnebago	Winnebago	2.03
26	11.56	22	Oswego	Kendall	2.20
27	11.56	22	Streator	LaSalle	2.53
28	11.56	22	Wisconsin		
29	11.56	22	Station	County	Precip.
30	11.56	22	Milwaukee	Milwaukee	3.44
			Waukesha	Waukesha	2.22
			Sharon	Walworth	6.11
			Delavan	Walworth	2.92

Total flow = 109 468 800 cu ft equiv. to a Rainfall of 0.075 in

July 1894

Day	Gauge reading C.C.N.	Discharge cu ft per sec	
1	11.56	22	Gauge readings as shown
2	11.56	22	were taken between 6 & 7 a.m.
3	11.53	16	
4	11.51	12	
5	11.51	12	
6	11.49	9	
7	11.49	9	
8	11.46	6	The total precipitation at
9	11.46	6	various points for this
10	11.43	3	month was as follows:—
11	11.43	3	Illinois
12	11.41	1	Station — County — Precipitation inches
13	11.39	0	Chicago — Cook — 0.60
14	11.39	0	Aurora — Kane — 0.62
15	11.36	0	Braidwood — Will — 0.46
16	11.36	0	Chemung — McHenry — 0.76
17	11.36	0	Dixon — Lee — 0.15
18	11.33	0	Ft. Sheridan — Lake — Trace
19	11.33	0	Galva — Henry — 0.99
20	11.31	0	Kankakee — Kankakee — 0.85
21	11.31	0	LaGrange — Cook — —
22	11.31	0	Ottawa — LaSalle — 0.80
23	11.31	0	Riley — McHenry — 0.31
24	11.29	0	Sycamore — DeKalb — 0.78
25	11.29	0	Winnebago — Winnebago — 1.48
26	11.26	0	Oswego — Kendall — 0.50
27	11.26	0	Streator — LaSalle
28	11.28	0	Wisconsin
29	11.23	0	Station — County — Precip.
30	11.23	0	Milwaukee — Milwaukee — 1.08
31	11.21	0	Waukesha — Waukesha — 1.16
			Sharon — Walworth — 0.80
			Delavan — Walworth — 1.13

Total flow = 10454400 cu ft equiv. to a Rainfall of 0.007 in

August 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	11.16	0
2	11.16	0
3	11.16	0
4	11.16	0
5	11.16	0
6	11.16	0
7	11.13	0
8	11.13	0
9	11.11	0
10	11.11	0
11	11.11	0
12	11.11	0
13	11.11	0
14	11.11	0
15	11.09	0
16	11.09	0
17	11.09	0
18	11.06	0
19	11.06	0
20	11.06	0
21	11.03	0
22	11.03	0
23	11.01	0
24	10.99	0
25	10.96	0
26	10.93	0
27	10.91	0
28	10.91	0
29	10.88	0
30	10.88	0
31	10.83	0

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.60
Aurora	Kane	1.79
Braidwood	Will	0.85
Chemung	McHenry	1.28
Dixon	Lee	0.92
Ft Sheridan	Lake	0.27
Galva	Henry	1.78
Kankakee	Kankakee	1.30
LaGrange	Cook	—
Ottawa	LaSalle	1.75
Riley	McHenry	1.33
Sycamore	DeKalb	0.95
Winnebago	Winnebago	1.27
Oswego	Kendall	1.49
Streator	LaSalle	—

Wisconsin

Station	County	Precip.
Milwaukee	Milwaukee	0.29
Waukesha	Waukesha	1.73
Sharon	Walworth	0.80
Delavan	Walworth	0.50

Total flow = 0

September 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	10.81	0	Gauge readings as shown		
2	10.81	0	were taken between 6 & 7 a.m.		
3	10.81	0			
4	11.26	0			
5	11.36	0			
6	11.31	0			
7	11.41	1			
8	11.46	.6	The total precipitation at		
9	12.21	203	various points for this		
10	12.06	144	month was as follows:—		
11	12.16	184	Illinois		
12	12.06	144	Station	County	Precipitation inches
13	11.96	112	Chicago	Cook	8.28
14	11.66	44	Aurora	Kane	7.07
15	11.56	22	Braidwood	Will	5.99
16	11.46	6	Chemung	McHenry	8.33
17	11.66	44	Dixon	Lee	3.20
18	11.66	44	Ft. Sheridan	Lake	6.56
19	11.66	44	Galva	Henry	5.17
20	11.61	32	Kankakee	Kankakee	8.44
21	11.53	16	LaGrange	Cook	8.87
22	11.46	6	Ottawa	LaSalle	7.18
23	11.41	1	Riley	McHenry	15.73
24	11.36	0	Sycamore	Dekalb	7.88
25	11.33	0	Winnebago	Winnebago	5.15
26	11.31	0	Oswego	Kendall	7.35
27	11.31	0	Streator	LaSalle	—
28	11.31	0	Wisconsin		
29	11.31	0	Station	County	Precip.
30	11.26	0	Milwaukee	Milwaukee	5.06
			Waukesha	Waukesha	4.55
			Sharon	Walworth	7.12
			Delavan	Walworth	6.44

Total flow = 90479200 cu ft equiv. to a Rainfall of 0.062 in.

October 1894

Day	Gauge reading C.C.W.	Discharge cu ft per sec
1	11.21	0
2	11.26	0
3	11.31	0
4	11.31	0
5	11.31	0
6	11.31	0
7	11.26	0
8	11.21	0
9	11.16	0
10	11.16	0
11	11.16	0
12	11.11	0
13	11.13	0
14	11.16	0
15	11.16	0
16	11.16	0
17	11.21	0
18	11.21	0
19	11.26	0
20	11.23	0
21	11.31	0
22	11.36	0
23	11.31	0
24	11.26	0
25	11.26	0
26	11.23	0
27	11.21	0
28	11.21	0
29	11.21	0
30	11.23	0
31	11.23	0

Gauge readings as shown were taken between 6 & 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.84
Aurora	Kane	1.68
Braidwood	Will	1.18
Chemung	McHenry	1.87
Dixon	Lee	0.99
Ft. Sheridan	Lake	2.49
Galva	Henry	1.16
Kankakee	Kankakee	0.50
LaGrange	Cook	1.04
Ottawa	LaSalle	1.63
Riley	McHenry	1.57
Sycamore	DeKalb	1.77
Winnebago	Winnebago	1.81
Oswego	Kendall	1.34
Streator	LaSalle	—

Wisconsin

Station	County	Precip.
Milwaukee	Milwaukee	2.05
Waukesha	Waukesha	2.37
Sharon	Walworth	1.63
Delavan	Walworth	2.11

Total flow = 0.

November 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec.			
1	11.26	0	Gauge readings as shown		
2	11.31	0	were taken between 6 + 7 AM.		
3	11.36	0			
4	11.36	0			
5	11.36	0			
6	11.36	0			
7	11.41	1			
8	11.41	1	The total precipitation		
9	11.46	6	at various points for this		
10	11.46	6	month was as follows:—		
11	11.46	6		Illinois	
12	11.36	0	Station	County	Precipitation inches
13	11.46	6	Chicago	Cook	1.18
14	11.46	6	Aurora	Kane	1.95
15	11.51	12	Braidwood	Will	1.68
16	11.51	12	Chemung	McHenry	2.27
17	11.49	9	Dixon	Lee	1.42
18	11.49	9	Ft. Sheridan	Lake	1.64
19	11.46	6	Galva	Henry	1.62
20	11.51	12	Kankakee	Kankakee	2.20
21	11.46	6	La Grange	Cook	1.45
22	11.46	6	Ottawa	La Salle	2.07
23	11.46	6	Riley	McHenry	2.06
24	11.49	9	Sycamore	DeKalb	1.96
25	11.46	6	Winnebago	Winnebago	1.79
26	11.46	6	Oswego	Kendall	1.79
27	11.43	3	Streator	La Salle	—
28	11.51	12		Wisconsin	
29	11.46	6	Station	County	Precip
30	11.51	12	Milwaukee	Milwaukee	1.68
			Waukesha	Waukesha	2.04
			Sharon	Walworth	2.38
			Delavan	Walworth	2.13

Total flow = 1416960 cu. ft. equiv. to a Rainfall of 0.0097 in.

December 1894

Day	Gauge reading C.C.D.	Discharge cu ft per sec
1	11.46	6
2	11.31	0
3	11.26	0
4	11.39	0
5	11.41	1
6	11.41	1
7	11.39	0
8	11.33	0
9	11.26	0
10	11.23	0
11	11.26	0
12	11.31	0
13	11.31	0
14	11.41	1
15	11.46	6
16	11.56	22
17	11.66	44
18	11.61	32
19	11.66	44
20	11.63	37
21	11.43	3
22	11.56	22
23	11.63	37
24	11.58	26
25	11.58	26
26	11.46	6
27	11.43	3
28	—	—
29	—	—
30	—	—
31	—	—

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.66
Aurora	Kane	0.96
Braidwood	Will	1.00
Chemung	McHenry	0.61
Dixon	Lee	0.53
Ft Sheridan	Lake	1.26
Galva	Henry	0.62
Kankakee	Kankakee	0.94
LaGrange	Cook	0.71
Ottawa	LaSalle	1.19
Riley	McHenry	0.44
Sycamore	DeKalb	0.74
Winnebago	Winnebago	0.33
Oswego	Kendall	0.76
Streator	LaSalle	—

Wisconsin

Station	County	Precip
Milwaukee	Milwaukee	0.84
Waukesha	Waukesha	0.51
Oconomowoc	Waukesha	0.61
Sharon	Walworth	1.23

January 1895

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	—	—	Gauge readings as shown		
2	—	—	were taken at 7 a.m.		
3	—	—			
4	—	—			
5	—	—			
6	—	—			
7	—	—			
8	11.26	0	The total precipitation		
9	11.26	0	at various points for this		
10	11.23	0	month was as follows:—		
11	11.41	0		Illinois	
12	11.41	0	Station	County	Precipitation inches
13	11.29	0	Chicago	Cook	2.15
14	11.23	0	Aurora	Kane	1.53
15	11.21	0	Braidwood	Will	1.82
16	11.19	0	Chemung	McHenry	1.47
17	11.16	0	Dixon	Lee	1.22
18	11.09	0	Ft. Sheridan	Lake	2.71
19	11.11	0	Galva	Henry	1.33
20	11.26	0	Kankakee	Kankakee	1.00
21	11.36	0	LaGrange	Cook	1.64
22	11.23	0	Ottawa	LaSalle	1.22
23	11.16	0	Riley	McHenry	2.09
24	11.11	0	Sycamore	DeKalb	1.35
25	11.01	0	Winnebago	Winnebago	1.42
26	10.96	0	Oswego	Kendall	1.33
27	10.96	0		Wisconsin	
28	10.96	0	Station	County	Precip.
29	10.96	0	Waukesha	Waukesha	1.55
30	10.91	0	Milwaukee	Milwaukee	1.78
31	10.91	0	Oconomowoc	Waukesha	1.11
			Sharon	Walworth	1.20
			Delavan	Walworth	1.01

February 1895

Day	Gauge reading C.C.D.	Discharge cu ft per sec.
1	10.86	0
2	11.26	0
3	11.26	0
4	11.16	0
5	11.16	0
6	11.16	0
7	11.13	0
8	11.13	0
9	11.13	0
10	11.13	0
11	11.13	0
12	11.36	0
13	11.36	0
14	11.36	0
15	11.46	6
16	11.41	1
17	11.36	0
18	11.33	0
19	11.29	0
20	11.23	0
21	11.23	0
22	11.23	0
23	11.23	0
24	11.31	0
25	11.41	1
26	12.83	442
27	13.96	1036
28	15.31	2109

Gauge readings as shown were taken at 7 A.M. The highest reading noted was 12 M. 28th – 15.41 = discharge of 2199 cu ft per sec.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.60
Aurora	Kane	0.50
Braidwood	Will	0.67
Chemung	McHenry	0.95
Dixon	Lee	0.43
Ft. Sheridan	Lake	0.32
Galva	Henry	0.19
Kankakee	Kankakee	0.19
LaGrange	Cook	0.45
Ottawa	LaSalle	0.70
Riley	McHenry	0.46
Sycamore	DeKalb	0.30
Winnebago	Winnebago	0.39
Oswego	Kendall	0.38

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	0.42
Milwaukee	Milwaukee	1.26
Oconomowoc	Waukesha	0.23
Sharon	Walworth	1.27
Delavan	Walworth	0.40

Total flow = 310608000 cu ft equiv. to a Rain fall of 0.21 in.

March. 1895.

Day	Gauge reading C.C.D.	Discharge cu ft per sec.
1	15.11	1919
2	14.66	1542
3	13.66	856
4	14.66	1542
5	13.86	976
6	12.96	494
7	12.66	380
8	12.46	284
9	12.46	284
10	12.46	284
11	12.76	418
12	12.56	330
13	12.56	330
14	12.21	203
15	12.21	203
16	12.16	184
17	12.16	184
18	11.96	99
19	11.96	99
20	11.86	90
21	12.06	144
22	12.11	164
23	12.11	164
24	12.06	144
25	12.01	124
26	11.93	104
27	11.96	99
28	11.86	90
29	11.84	85
30	11.81	77
31	11.81	77

Gauge readings as shown were taken at 7 AM

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.32
Aurora	Kane	1.14
Braidwood	Will	1.04
Chemung	McHenry	2.18
Dixon	Lee	0.83
Ft Sheridan	Lake	0.45
Galva	Henry	0.35
Kankakee	Kankakee	1.02
LaGrange	Cook	0.85
Ottawa	LaSalle	0.82
Riley	McHenry	1.32
Sycamore	DeKalb	1.03
Winnebago	Winnebago	1.90
Oswego	Kendall	1.35

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	0.53
Milwaukee		0.74
Oconomowoc	Waukesha	0.50
Sharon	Walworth	0.74
Delavan	Walworth	1.27

Total flow = 1034 467 200 cu ft. equiv. to a Rainfall of 0.71 in.

April 1895.

Day	Gauge reading CCW	Discharge cu ft per sec			
1	11.81	77	Gauge readings as shown		
2	12.04	136	were taken at 7 A.M.		
3	12.14	176			
4	12.14	176			
5	12.14	176			
6	12.06	144			
7	11.96	99			
8	12.26	218	The total precipitation at		
9	12.76	418	various points for this		
10	13.41	706	month was as follows:—		
11	13.11	555	Illinois		
12	12.81	434	Station	County	Precipitation inches
13	12.56	330	Chicago	Cook	0.86
14	12.36	248	Aurora	Kane	1.48
15	12.21	203	Braidwood	Will	1.92
16	12.14	176	Chemung	McHenry	2.52
17	12.06	144	Dixon	Lee	1.17
18	11.96	103	Ft. Sheridan	Lake	2.50
19	11.86	90	Galva	Henry	1.03
20	11.81	78	Kankakee	Kankakee	2.81
21	11.76	67	LaGrange	Cook	1.17
22	11.68	50	Ottawa	LaSalle	2.02
23	11.58	26	Riley	McHenry	1.81
24	11.56	22	Sycamore	DeKalb	1.24
25	11.56	22	Winnebago	Winnebago	0.70
26	11.61	33	Oswego	Kendall	1.56
27	11.48	8	Wisconsin		
28	11.51	12	Station	County	Precip.
29	11.56	22	Waukesha	Waukesha	0.78
30	11.56	22	Milwaukee		1.48
			Oconomowoc	Waukesha	—
			Sharon	Walworth	2.13
			Delavan	Walworth	1.09

Total flow = 429494400 cu ft equiv. to a Rainfall of 0.29 in.

May 1895

Day	Gauge reading CCS	Discharge cu ft per sec
1	11.56	22
2	11.51	12
3	11.46	6
4	11.46	6
5	11.51	12
6	11.66	44
7	11.81	78
8	11.76	66
9	11.81	78
10	11.86	88
11	11.96	110
12	12.31	233
13	12.24	212
14	12.08	152
15	12.06	144
16	11.91	100
17	11.86	88
18	11.76	66
19	11.74	62
20	11.68	50
21	11.66	45
22	11.64	42
23	11.61	34
24	11.64	42
25	11.58	26
26	11.56	22
27	11.51	12
28	11.51	12
29	11.51	12
30	11.46	6
31	11.46	6

Gauge readings as shown were taken at 7 am.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.99
Aurora	Kane	3.34
Braidwood	Will	—
Chemung	McHenry	4.96
Dixon	Lee	4.46
Ft. Sheridan	Lake	3.70
Galva	Henry	2.53
Kankakee	Kankakee	2.64
La Grange	Cook	2.24
Ottawa	La Salle	1.06
Riley	McHenry	2.97
Sycamore	DeKalb	2.52
Winnebago	Winnebago	4.07
Oswego	Kendall	3.27

Wisconsin

Station	County	Precip
Waukesha	Waukesha	5.01
Milwaukee		1.37
Oconomowoc	Waukesha	4.82
Sharon	Walworth	3.86
Delavan	Walworth	3.54

Total flow = 163 123 200 cu ft equiv to a Rainfall of 0.11 in

June 1895.

Day	Gauge reading CCN	Discharge cuft per sec
1	11.44	4
2	11.44	4
3	11.41	1
4	11.38	0
5	11.36	0
6	11.34	0
7	11.36	0
8	11.34	0
9	11.31	0
10	11.31	0
11	11.31	0
12	11.31	0
13	11.31	0
14	11.31	0
15	11.31	0
16	11.31	0
17	11.31	0
18	11.28	0
19	11.26	0
20	11.21	0
21	11.18	0
22	11.16	0
23	11.16	0
24	11.16	0
25	11.16	0
26	11.16	0
27	11.13	0
28	11.11	0
29	11.11	0
30	11.08	0

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	1.79
Aurora	Kane	1.66
Braidwood	Will	—
Chemung	McHenry	2.11
Dixon	Lee	1.62
Ft Sheridan	Lake	2.60
Galva	Henry	1.57
Kankakee	Kankakee	1.11
LaGrange	Cook	2.00
Ottawa	LaSalle	1.02
Riley	McHenry	1.68
Sycamore	DeKalb	2.20
Winnebago	Winnebago	1.89
Oswego	Kendall	1.64

Wisconsin

Station	County	Precip
Waukesha	Waukesha	2.29
Milwaukee		3.04
Oconomowoc	Waukesha	1.30
Sharon	Walworth	3.15
Delavan	Walworth	2.63

Total flow = 777 600 cuft equiv. to a Rainfall of 0.0005 in.

July 1895.

Day	Gauge reading C.C.W.	Discharge cu ft per sec
1	11.06	0
2	11.06	0
3	11.06	0
4	11.06	0
5	11.06	0
6	11.06	0
7	11.06	0
8	11.06	0
9	11.03	0
10	11.03	0
11	11.03	0
12	11.01	0
13	11.01	0
14	10.98	0
15	10.98	0
16	10.96	0
17	10.96	0
18	10.93	0
19	11.03	0
20	11.06	0
21	11.06	0
22	11.06	0
23	11.06	0
24	11.06	0
25	11.06	0
26	11.06	0
27	11.06	0
28	11.06	0
29	11.06	0
30	11.08	0
31	11.08	0

Total flow = 0

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	2.42
Aurora	Kane	3.23
Braidwood	Will	—
Chemung	McHenry	2.91
Dixon	Lee	4.59
Ft Sheridan	Lake	3.30
Galva	Henry	5.58
Kankakee	Kankakee	2.53
LaGrange	Cook	—
Ottawa	LaSalle	4.79
Riley	McHenry	3.43
Sycamore	DeKalb	3.10
Winnebago	Winnebago	3.89
Oswego	Kendall	3.61

Wisconsin

Station	County	Precip.
Waukesha	Waukesha	1.79
Milwaukee		1.58
Oconomowoc	Waukesha	1.63
Sharon	Walworth	4.07
Delavan	Walworth	5.33

August 1895

Day	Gauge reading C. C. D.	Discharge cu ft per sec.
1	11.13	0
2	11.13	0
3	11.13	0
4	11.13	0
5	11.13	0
6	11.11	0
7	11.11	0
8	11.08	0
9	11.06	0
10	11.06	0
11	11.06	0
12	11.06	0
13	11.04	0
14	11.01	0
15	11.01	0
16	11.01	0
17	10.98	0
18	10.98	0
19	10.96	0
20	10.96	0
21	10.93	0
22	10.88	0
23	10.86	0
24	11.28	0
25	11.43	3
26	11.36	0
27	11.41	1
28	11.36	0
29	11.61	32
30	11.58	26
31	11.78	71

Gauge readings as shown were taken at 7 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	6.49
Aurora	Kane	4.80
Joliet	Will	2.96
Chemung	McHenry	3.06
Dixon	Lee	2.83
Ft. Sheridan	Lake	3.81
Galva	Henry	2.74
Kankakee	Kankakee	2.61
La Grange	Cook	5.69
Ottawa	LaSalle	2.26
Riley	McHenry	3.94
Sycamore	DeKalb	3.06
Winnebago	Winnebago	2.92
Oswego	Kendall	5.00
Wisconsin		
Waukesha	Waukesha	2.61
Milwaukee		2.83
Oconomowoc	Waukesha	3.22
Sharon	Walworth	3.49
Delavan	Walworth	4.12

Total flow = 11,491,200 cu ft equiv. to a Rainfall of 0.0077"

September 1895

Day	Gauge reading C.C.D.	Discharge cubft per sec.
1	11.78	71
2	11.76	66
3	11.56	22
4	11.46	6
5	11.46	6
6	11.38	0
7	11.33	0
8	11.31	0
9	11.26	0
10	11.86	89
11	12.01	124
12	12.16	184
13	12.08	152
14	11.88	93
15	11.76	66
16	11.71	55
17	11.56	22
18	11.48	8
19	11.46	6
20	11.41	1
21	11.33	0
22	11.31	0
23	11.28	0
24	11.36	0
25	11.36	0
26	11.41	1
27	11.31	0
28	11.31	0
29	11.31	0
30	11.31	0

Gauge readings as shown were taken at 6:15 a.m.

The total precipitation at various points for this month was as follows:

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.89
Aurora	Kane	1.17
Joliet	Will	0.93
Dixon	Lee	1.81
Ft. Sheridan	Lake	4.88
Galva	Henry	5.17
Chemung	McHenry	4.74
Kankakee	Kankakee	1.29
La Grange	Cook	1.10
Ottawa	LaSalle	1.47
Riley	McHenry	2.16
Sycamore	DeKalb	0.75
Winnebago	Winnebago	2.29
Oswego	Kendall	0.59
Wisconsin		
Waukesha	Waukesha	1.56
Milwaukee		1.82
Oconomowoc	Waukesha	1.43
Sharon	Walworth	3.85
Delavan	Walworth	2.93

Total flow = 83,980,800 cub ft equiv. to a Rainfall of 0.0574"

October 1895.

Day	Gauge reading C.C.D.	Discharge cu ft per sec.
1	11.28	0
2	11.23	0
3	11.21	0
4	11.21	0
5	10.96	0
6	11.18	0
7	11.23	0
8	11.31	0
9	11.31	0
10	11.31	0
11	11.31	0
12	11.28	0
13	11.28	0
14	11.31	0
15	11.33	0
16	11.33	0
17	11.31	0
18	11.31	0
19	11.28	0
20	11.26	0
21	11.26	0
22	11.26	0
23	11.26	0
24	11.26	0
25	11.26	0
26	11.26	0
27	11.26	0
28	11.26	0
29	11.26	0
30	11.26	0
31	11.26	0

Gauge readings as shown were taken at 6:10 a.m.

The total precipitation at various points for this month was as follows:—

Illinois

Station	County	Precipitation inches
Chicago	Cook	0.51
Aurora	Kane	1.11
Joliet	Will	0.67
Chemung	McHenry	0.66
Dixon	Lee	0.82
Ft. Sheridan	Lake	0.41
Galva	Henry	0.87
La Grange	Cook	0.77
Ottawa	La Salle	1.16
Kankakee	Kankakee	1.52
Riley	McHenry	0.41
Sycamore	DeKalb	0.55
Winnebago	Winnebago	0.80
Oswego	Kendall	1.05

Wisconsin

Station	County	Precipitation inches
Waukesha	Waukesha	0.67
Milwaukee		0.52
Oconomowoc	Waukesha	0.63
Sharon	Walworth	0.72
Delavan	Walworth	0.49

Total flow = 0.

November 1895

Day	Gauge reading C.C.D.	Discharge cub ft per sec
1	11.26	0
2	11.26	0
3	11.26	0
4	11.26	0
5	11.21	0
6	11.21	0
7	11.21	0
8	11.26	0
9	11.34	0
10	11.41	1
11	11.46	6
12	11.46	6
13	11.41	1
14	11.36	0
15	11.36	0
16	11.36	0
17	11.36	0
18	11.36	0
19	11.36	0
20	11.36	0
21	11.36	0
22	11.36	0
23	11.36	0
24	11.38	0
25	11.38	0
26	11.41	1
27	11.41	1
28	11.41	1
29	11.41	1
30	11.41	1

The gauge readings as shown were taken at 6:10 a.m.

The total precipitation at various points for this month was as follows:

Illinois

Station	County	Precipitation inches
Chicago	Cook	5.60
Aurora	Kane	5.41
Joliet	Will	2.90
Chemung	McHenry	2.10
Dixon	Lee	2.50
Ft. Sheridan	Lake	2.14
Galva	Henry	2.23
La Grange	Cook	5.09
Ottawa	LaSalle	5.27
Kankakee	Kankakee	3.02
Riley	McHenry	2.69
Sycamore	DeKalb	3.71
Winnebago	Winnebago	3.07
Oswego	Kendall	4.53
Wisconsin		
Waukesha	Waukesha	2.11
Milwaukee		2.99
Oconomowoc	Waukesha	1.81
Sharon	Walworth	3.68
Delavan	Walworth	1.93

Total flow = 1641,600 cub ft equiv. to a Rainfall of 0.00112"

December 1895

Day	Gauge reading C. C. D.	Discharge cu ft per sec.
1	11.41	1
2	11.41	1
3	11.41	1
4	11.38	0
5	11.36	0
6	11.36	0
7	11.36	0
8	11.36	0
9	11.36	0
10	11.36	0
11	11.33	0
12	11.33	0
13	11.31	0
14	11.31	0
15	11.31	0
16	11.31	0
17	11.36	0
18	11.86	89
19	13.16	580
20	16.96	4050
21	18.36	6268
22	17.76	5240
23	16.86	3904
24	15.66	2486
25	15.36	2154
26	15.11	1919
27	14.86	1322
28	13.86	976
29	13.46	736
30	13.06	534
31	12.56	330

Gauge readings as shown were taken at 6:10 a.m.

The total precipitation at various points for this month was as follows:—

Station	County	Precipitation inches
Illinois		
Chicago	Cook	6.76
Aurora	Kane	5.89
Joliet	Will	6.62
Chemung	McHenry	2.59
Dixon	Lee	2.00
Ft. Sheridan	Lake	—
Galva	Henry	4.20
La Grange	Cook	6.04
Ottawa	LaSalle	5.77
Kankakee	Kankakee	—
Riley	McHenry	3.00
Sycamore	DeKalb	3.38
Winnebago	Winnebago	2.07
Oswego	Kendall	6.10
Wisconsin		
Waukesha	Waukesha	1.82
Milwaukee		2.60
Oconomowoc	Waukesha	1.25
Sharon	Walworth	3.44
Delavan	Walworth	2.23

Total flow = 2,638,742,400 cu ft equiv. to a Rainfall of 1.803"

January 1896.

Day	Gauge reading C.C.D.	Discharge cu ft per sec.
1	12.46	284
2	12.56	330
3	12.66	380
4	12.74	412
5	12.74	412
6	12.56	330
7	12.36	248
8	12.11	164
9	11.96	111
10	11.96	111
11	11.81	77
12	11.96	111
13	11.81	77
14	11.71	55
15	11.64	39
16	11.59	28
17	11.54	18
18	11.49	9
19	11.46	6
20	11.46	6
21	11.46	6
22	11.46	6
23	11.51	12
24	11.81	77
25	11.96	111
26	12.06	144
27	12.06	144
28	12.09	156
29	12.09	156
30	12.11	164
31	12.11	164

Gauge readings as shown were taken at 6:10 a.m.

The total precipitation at various points for this month was as follows:

Station	County	Precipitation inches
Illinois		
Chicago	Cook	1.12
Aurora	Kane	1.21
Joliet	Will	1.14
Chemung	McHenry	0.99
Dixon	Lee	0.65
Fort Sheridan	Lake	0.52
Galva	Henry	1.17
La Grange	Cook	1.16
Ottawa	La Salle	1.37
Kankakee	Kankakee	—
Riley	McHenry	0.61
Sycamore	DeKalb	0.50
Winnebago	Winnebago	0.65
Oswego	Kendall	1.09
Wisconsin		
Waukesha	Waukesha	0.43
Milwaukee		1.22
Oconomowoc	Waukesha	0.64
Sharon	Walworth	0.75
Delavan	Walworth	0.59

Total flow = 375,667,200 cu ft. equiv. to a Rainfall of 0.2567"

February 1896

Day	Gauge reading C.C.D	Discharge cu ft. per sec.			
1	12.11	164	Gauge readings as shown		
2	12.11	164	were taken at 6:15 a.m.		
3	12.16	184			
4	12.16	184			
5	12.11	164			
6	11.96	111			
7	11.91	100			
8	11.86	89	The total precipitation at		
9	11.86	89	various points for this		
10	11.86	89	month was as follows:-		
11	11.86	89	Illinois		
12	11.86	89	Chicago	Cook	3.48
13	11.86	89	Aurora	Kane	1.93
14	11.86	89	Joliet	Will	2.07
15	11.86	89	Chemung	McHenry	1.93
16	11.86	89	Dixon	Lee	0.74
17	11.86	89	Ft. Sheridan	Lake	1.06
18	11.86	89	Galva	Henry	0.80
19	11.81	77	La Grange	Cook	2.39
20	11.79	73	Ottawa	La Salle	1.65
21	11.79	73	Kankakee	Kankakee	—
22	11.81	77	Riley	McHenry	1.56
23	11.91	100	Sycamore	DeKalb	2.03
24	12.46	284	Winnebago	Winnebago	1.54
25	13.86	976	Oswego	Kendall	1.90
26	16.24	3088	Wisconsin		
27	16.54	3472	Waukesha	Waukesha	0.89
28	17.06	4194	Milwaukee		1.36
29	16.56	3498	Oconomowoc	Waukesha	0.44
			Sharon	Walworth	1.58
			Delavan	Walworth	0.89

Total flow = 1,551,916,786 cu ft. equiv. to a Rainfall of 1.0603"

March 1896.

Day	Gauge reading C.C.N.	Discharge cu ft. per sec.			
1	14.91	1749	Gauge readings as shown		
2	14.06	1096	were taken at 6:15 a.m.		
3	13.46	736			
4	13.11	555			
5	12.86	454			
6	12.79	427			
7	13.46	736			
8	13.66	856	The total precipitation at		
9	13.64	844	various points for this month		
10	13.46	736	was as follows:		
11	13.36	680		Illinois	
12	13.11	555	Chicago	Cook	1.26
13	12.66	380	Aurora	Kane	1.71
14	12.61	355	Joliet	Will	1.15
15	12.39	257	Chemung	McHenry	3.48
16	12.31	233	Dixon	Lee	0.81
17	12.31	233	Ft. Sheridan	Lake	2.53
18	12.39	257	Galva	Henry	0.79
19	12.51	305	LaGrange	Cook	1.04
20	12.81	434	Ottawa	LaSalle	1.32
21	12.71	403	Kankakee	Kankakee	—
22	12.81	434	Riley	McHenry	1.85
23	12.86	454	Sycamore	DeKalb	1.44
24	12.86	454	Winnebago	Winnebago	1.28
25	12.79	427	Oswego	Kendall	1.71
26	12.81	434		Wisconsin	
27	12.66	380	Waukesha	Waukesha	1.82
28	12.66	380	Milwaukee		2.82
29	13.34	670	Oconomowoc	Waukesha	1.30
30	14.56	1468	Sharon	Walworth	1.73
31	14.41	1357	Delavan	Walworth	1.51

Total flow = 1,619,049,600 cu ft. equiv. to a Rainfall of 1.1062"

April 1896.

Day	Gauge reading C.C.D.	Discharge cu ft per sec			
1	13.91	1006	Gauge readings as shown were taken at 6:10 A.M.		
2	13.64	844			
3	13.26	630			
4	13.06	534			
5	12.66	380			
6	12.56	330			
7	12.49	296			
8	12.41	264	The total precipitation at various points for this month was as follows:-		
9	12.24	212			
10	12.16	184			
11	12.16	184	Illinois		
12	12.26	218	Chicago	Cook	2.79
13	12.36	248	Aurora	Kane	4.17
14	12.56	330	Joliet	Will	2.82
15	12.86	454	Chemung	McHenry	6.81
16	12.89	466	Dixon	Lee	3.62
17	12.76	418	Ft. Sheridan	Lake	3.13
18	12.56	330	Galva	Henry	4.24
19	12.36	248	La Grange	Cook	4.21
20	12.26	218	Ottawa	La Salle	3.38
21	12.86	454	Kankakee	Kankakee	—
22	13.26	630	Riley	McHenry	2.97
23	12.96	494	Sycamore	DeKalb	2.74
24	13.61	826	Winnebago	Winnebago	3.63
25	13.61	826	Oswego	Kendall	3.48
26	13.06	534	Wisconsin		
27	12.86	454	Waukesha	Waukesha	4.11
28	12.69	395	Milwaukee		3.85
29	12.56	330	Oconomowoc	Waukesha	5.29
30	12.41	264	Sharon	Walworth	3.64
			Delavan	Walworth	3.75

Total flow = 1,123,286,400 cu ft. equiv. to a Rainfall of 0.7675"

May 1896

Day	Gauge reading C.C.D.	Discharge cu ft per sec	
1			Gauge readings as shown
2			were taken at am
3			
4			
5			
6			
7			
8			The total precipitation at
9			various points for this month
10			was as follows:—
11			Illinois
12			Chicago Cook
13			Aurora Kane
14			Joliet Will
15			Chemung McHenry
16			Dixon Lee
17			Ft. Sheridan Lake
18			Galva Henry
19			La Grange Cook
20			Ottawa LaSalle
21			Kankakee Kankakee
22			Riley McHenry
23			Sycamore DeKalb
24			Winnebago Winnebago
25			Oswego Kendall
26			Wisconsin
27			Waukesha Waukesha
28			Milwaukee
29			Oconomowoc Waukesha
30			Sharon Walworth
31			Delavan Walworth

TABLE XXXII.

DESPLAINES RIVER BASIN ABOVE RIVERSIDE.

RAINFALL RUNNING "OFF" AND ACTUALLY FALLING "ON."

MONTH.	1886		1887		1888		1889		1890		1892		1893		1894		1895		1896	
	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	On		
January....	....	....	0.89	3.13	1.37	1.56	0.287	1.64	......		....	....	0.0084	2.08	0.50	1.55	.....	2.15	0.25667	1.12
February...	....	..	5.59	5.10	2.50	1.51	0.014	1.31	.....	....	......	..	0.31	2.44	1.06	2.13	0.21	1.60	1.06033	3.18
March	....	....	2.64	0.89	4.84	2.99	0.426	1.43	.....	..	....	.....	5.15	1.69	3.05	2.66	0.71	1.32	1.1062	1.26
April........	.....	....	0.52	0.46	....	....	1.13	2.35	....	....	......	.....	1.79	4.16	0.76	2.65	0.29	0.83	0.7675	2.79
May........	....	1.00	0.126	1.38	.....	....	0.39	5.38	......	....	4.24	6.77	1.31	1.93	1.90	3.35	0.11	1.99	....	....
June........	0.155	0.91	0.015	1.63	......	....	1.26	2.93	......	...	6.04	10.58	1.37	3.59	0.075	1.96	0.00005	1.79	....	...
July.........	0.142	1.53	0.331	1.05	....		1.09	9.56	......	2.57	0.79	2.23	0.14	3.08	0.007	0.60	0.00	2.42	....	....
August......	0.0098	3.38	0.175	3.35	....	....	0.45	0.39	0.018	2.58	0.025	1.85	0.0013	0.18	0.00	0.60	0.00767	6.49	......	....
September..	0.028	6.93	0.216	4.03	......	0.98	0.00	2.75	0.012	1.39	0.015	1.34	0.00	1.98	0.062	8.28	0.05738	0.89	.....	....
October.....	0.0073	1.42	0.626	2.03	0.00	2.95	0.00	1.82	0.021	4.20	0.0032	1.54	0.0176	1.75	0.00	0.81	0.00	0.51	....	....
November..	0.00077	1.66	.....	2.41	0.10	2.89	0.006	3.49	0.036	1.59	0.021	2.68	0.0012	2.45	0.0097	1.18	0.00112	5.60	......	...
December...	0.00	1.76	....	3.67	0.00	1.94	....	1.90	......	1.25	0.040	1.63	0.265	2.14	....	1.66	1.80289	6.76	....	....
Total........			11.132	29.13			5.053	34.95					10.3635	27.47	7.4237	27.46	3.18911	32.38		

VIII.

NOTES ABOUT THE GEOLOGY AND HYDROLOGY OF THE GREAT LAKES.

By P. Vedel, M. W. S. E.

Read June 3, 1896.

The system of the Great Lakes and St. Lawrence River extends between the forty-first and forty-ninth parallel over 2,500 miles from the ocean into the heart of the North American continent. About 5,500 cubic miles, or perhaps one-half of all the fresh water in rivers and lakes on the surface of the globe, are stored in this vast inland sea. The tiny St. Louis River and insignificant Chicago River discharge into Lakes Superior and Michigan. Through St. Mary's River and the Straits of Mackinac the waters pass into Georgian Bay and Lake Huron, and through St. Clair River, Lake St. Clair and Detroit River they proceed to Lake Erie. Through the Niagara River speeds the overflow of the four upper lakes, leaping over the falls, into Lake Ontario, whence the majestic St. Lawrence River carries it off to the ocean. The shores of eight of the United States and two of the provinces of Canada are washed by these waters. A larger fleet plies between their harbors, carrying greater riches of foods and minerals than on any other lakes or seas in the world. Nature has lavished her most beautiful scenery on some of the shores and manifests herself in the famous waterfalls in her most imposing grandeur. A study—or even a summary only of what is known—of the nature and origin of this system will therefore always be interesting and instructive.

GEOLOGY OF THE LAKE REGION.

Modern science has but partially lifted the veil that covers the geological history of the Great Lakes. Of some 270,000 square miles of catchment basin about 96,000 square miles are covered by the lakes. Over 88,000 square miles of this water expanse form the area of the upper lakes, dammed up by Niagara's limestone rocks to about 600 feet above tidewater. Ancient bays of the ocean have been landlocked; inland seas, larger than any of modern

times, have been born and have vanished again; torrents have broken through barriers and valleys have been eroded and flooded; the earth crust has undergone subsidences and uplifts, has been warped and tilted; and the lakes, as we know them now, have been separated and connected, have expanded and contracted and have sent their waters through the Mississippi and its tributaries to the Gulf of Mexico or poured them into the Atlantic through other outlets than that of the Niagara and St. Lawrence rivers.

North of the lake region rises the Laurentian highland, encircling the Hudson Bay. Towards east the Appalachian ranges and towards west the Cordilleran system and Rocky Mountains enclose the great central valley, which is drained by the lakes and St. Lawrence River to the Atlantic, by the Mississippi to the Gulf of Mexico, and by the Red River of the North and Lake Winnipeg to the Hudson Bay. Only low divides separate these drainage basins. Between the Green Mountains of New England and the Catskills and Adirondacks, and between the latter and the Allegheny Plateau, the valleys of the Hudson River with Lake Champlain and the Mohawk River connect the lake region with the seaboard.

The lands that border the northern shores of Lake Huron with Georgian Bay and Lake Superior belong, with exception of minor areas, to the Archaean system* (Laurentian granites, syenites and gneisses, Coutchiching and Keewatin schists, Huronian quartzites and graywackes, and volcanic traps), which also crops out on the south shore of Lake Superior in northern Wisconsin and Michigan (Laurentian granites, Huronian iron-bearing quartzites and diorites, Keweenian copper-bearing traps and conglomerates.) On the western and southern shores of Lake Superior the Cambrian system covers a narrow strip of land in Canada from Lake Nepigon and Black Bay to the international boundary line (Animikie silicious breccias and black slates and sandstones, Neepigon and Keweenian rocks) and a larger part of Minnesota, Wisconsin and the upper peninsula of Michigan (Potsdam sandstone, Lower Magnesian limestone, St. Peter's sandstone, Trenton limestone, Hudson River shale). It borders the western and southern shores of Green Bay from Big Bay de Noquette to near Sturgeon Bay, extends over Sugar, Neebish and St. Joseph islands to the Canadian side of St. Mary's River, rises above water on the northern part of Drummond and Grand Manitoulin, on Cloche and surrounding islands, and passes from there under Georgian Bay to reappear at its inner end, at Nottawasaga Bay, whence it continues across the Canadian peninsula and around the northern and eastern shores of Lake Ontario (Potsdam sandstone, calciferous sandrock, Black River and Birdseye limestones of New York, Trenton limestone of Canada, Utica slate, Hudson River and Lorrain shales). The northern shores of Lake

*In connection with this sketch the geological surveys of New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin, Minnesota and Canada may be consulted.

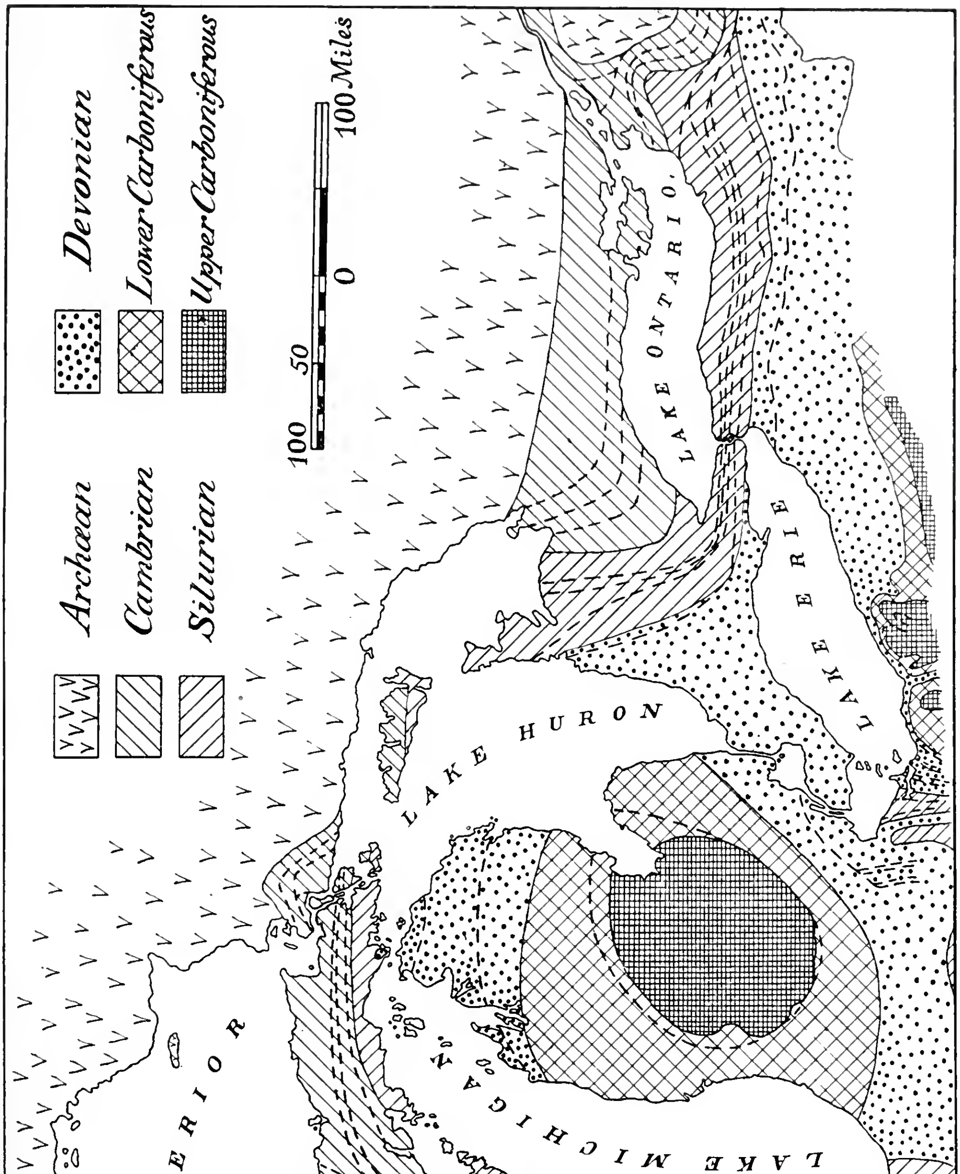

Fig. 94. Approximate Geological Map of Lake Region.

Michigan to Big Bay de Noquette, its western shores from Sturgeon Bay and the headland east of Green Bay southward, and its southern extremity belong to the Silurian (upper) age (Niagara limestone), which also appears on a short stretch of the southwestern shore of Lake Erie in Ottawa and Sandusky counties, Ohio (Niagara group, Salina group). From the upper peninsula of Michigan it continues over the southern part of Drummond and the Manitoulin islands to the headland that separates Lake Huron from Georgian Bay and, bordering the southern shore of the latter, it stretches across the Canadian peninsula to the northeast end of Lake Erie at the entrance to the Niagara River and to the west end of Lake Ontario, around the western and southern shores of which it extends to a little east of Oswego, N. Y. (Oneida conglomerates, Medina sandstone, Clinton, Niagara, Onondaga salt, Lower Helderberg group). With exception of the outcrops of Silurian rocks at its southwestern and northeastern ends Lake Erie is surrounded by Devonian formations (Oriskany sandstone, corniferous limestones, Hamilton group, Portage and Chemung group of New York, Erie shale of Ohio), which also surround Lake St. Clair and encircle the south end of Lake Huron, forming the southern part of Ontario and southeastern part of Michigan and extending across the base of the lower peninsula to the southeastern shore of Lake Michigan (Helderberg group, black shale). The northern part of the lower peninsula from near Au Sable on Lake Huron to near Frankfort on Lake Michigan, with the adjoining Manitou islands, Bois Blanc and Mackinac islands, belongs also to the Devonian system, which stretches across the straits of Mackinac and reappears at a single point on the upper peninsula, at Rabbit's Back Peak, near Point St. Ignace (Upper Helderberg, Hamilton group, black shale). Although in Ohio the Lower Carboniferous system approaches to within a short distance of Lake Erie it does not reach the shore there at any point. But on the Michigan peninsula it forms the western shore of Lake Huron, south and north of Saginaw Bay (Waverly group, carboniferous limestone), and the eastern shore of Lake Michigan (Waverly). And encircled by that, the kidney-shaped Michigan coal measures of the Upper Carboniferous age border the inner end of Saginaw Bay. These are the monuments that tell the earlier history of the lake region. Its later history, which concerns us more particularly, is to be read in the quaternary detrital formations and drift deposits that cover nearly the whole area and between which and the paleozoic rocks the intervening members of the geological series are entirely missing.

With exception of the driftless area in southwestern Wisconsin, which in reality belongs to the Mississippi basin, the lake region bears everywhere testimony of glacial action in the drift, with its boulders, gravels and clays, striated rocks, kettle holes, drumlins, kames, long and narrow lakes, etc. The unstratified drift or till is over a large area covered with more or less stratified deposits of lacustrine origin, such as the red clays of Michigan and Wisconsin, Erie clay of Ohio, Saugeen clay of Ontario, and Leda clay (upper

and lower) of eastern Canada, or with semi-stratified, subaqueous, floe till, deposited from floating icebergs. On top of these deposits is found in some places a stratum of carbonaceous matter, with logs and trees and insects, designated by Newberry as "forest beds" and also known as "dirt beds," and over that are other deposits of clay, gravel and boulders known as "lacustrine drift" and "iceberg drift," or "saxicava sand." The terminal moraine of the great glacier—which, descending both northward and southward from the Laurentian highlands, covered most of the northern states with several thousand feet of ice and left a territory of over one million square miles buried under fifty feet, and in some places 100 to 200 feet, of glacial debris—has been traced through New York, Pennsylvania, Ohio, Indiana, Illinois, Missouri and farther west. Another more northern terminal moraine "of the second glacial epoch" (Chamberlain) or "of retrocession" (Cook) has also been traced from Cape Cod, following the divide between St. Lawrence and the Mohawk River, coinciding with the older moraine from western Pennsylvania to Michigan, forming a great loop around Lake Michigan to the Wisconsin Kettle Range, which extends in southwesterly direction from Green Bay, and thence continued in a series of loops west of Lake Michigan, south of Lake Superior and farther west. This moraine and the interglacial forest beds are not absolute evidence of two glacial epochs separated by a warmer period, but may be explained by local recession and readvancement of the lobes of the glacier. Sir I. W. Dawson* considers the glacial views, held by most American authors,† as extreme and sees in the "terminal moraine" only the margin of a vast arctic sea laden with fields of floating, boulder-carrying ice, instrumental in forming the Great Lakes and the till.

A series of old shore lines or beaches and terraces are found around the Great Lakes at different elevations until about 1,400 feet above tide water. They follow in stairlike succession and consist of ridges of stratified gravel and sand with the false bedding of beach formations, sometimes twenty-five feet high above the frontal plain and usually less than 500 feet wide, with often a lagune-like depresssion behind them. Most of these shore lines rise more or less gradually in certain directions, generally north and east. Larger and differently shaped lakes have therefore in former times covered the territory, the water, after having receded a certain distance, remaining stationary for a while until beaches were formed and clay (Red clays, Erie clays) deposited. And a warping of the earth crust, with a regional uplift of some parts and subsidence of others, must have taken place or the land has at the time when the beaches were formed been depressed both north and east, per-

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*Canadian Ice Age, by I. W. Dawson, Montreal, 1894.

†The Ice Age in North America, by G. F. Wright, New York, 1889.

haps by the weight of the ice, for the shore lines must originally have been horizontal.

All the Great Lakes occupy true rock basins, eroded probably by the glacier, though to some extent possibly formed by a subsidence due to the weight of the ice. These basins, with exception of that of Lake Erie, all reach down below the level of the ocean. Lake Superior is partially situated in a synclinal trough, the older rocks on its shores dipping toward the center of the lake. It was therefore first formed by a subsidence of its bottom or an upheaval of the surrounding country in Keweenian times, or perhaps during the Cambrian age. It was subsequently filled by Cambrian and Silurian deposits, in which it was finally excavated by glacial action.

In preglacial times the region of the Great Lakes consisted of a system of river valleys where later the lakes were formed. The continent was then many hundred, perhaps over seven hundred, feet higher than now and the rivers gradually excavated their channels to a depth which is now below the bed of the ocean. The Michigan basin and Superior basin, the synclinal trough of which was filled with Cambrian and Silurian sediments, were deeply carved and creased by a system of rivers, which were connected through the upper peninsula of Michigan and drained to the Mississippi val-

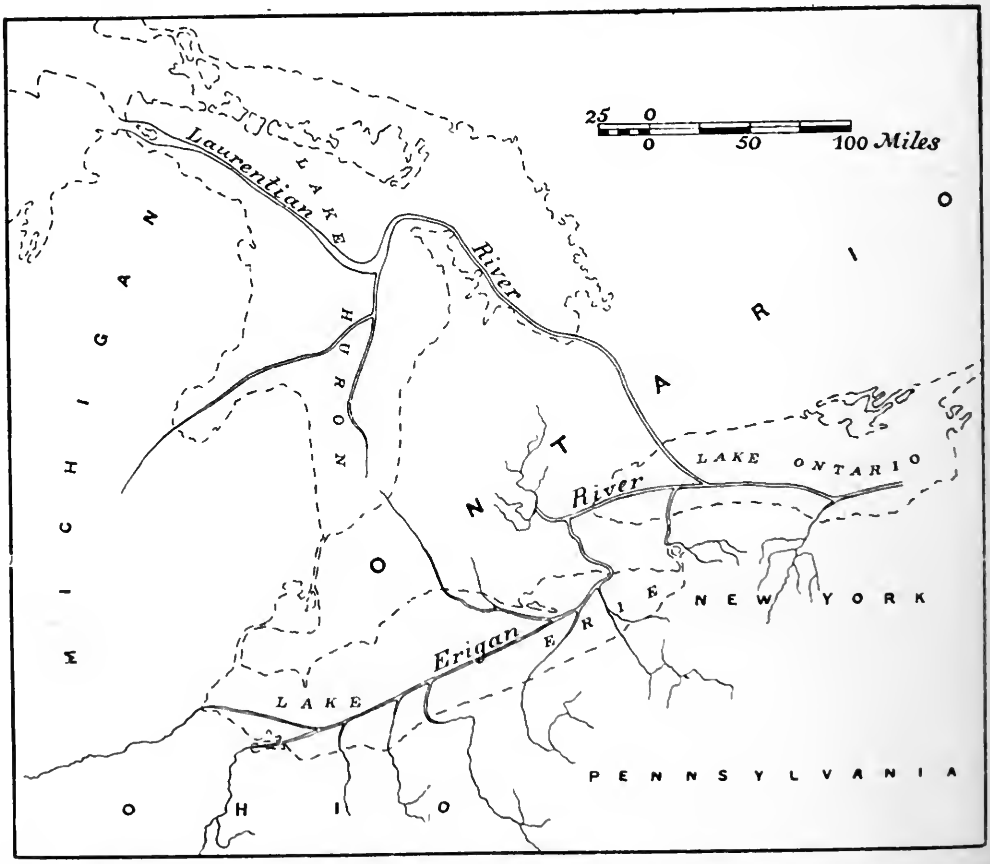

FIG. 95. PREGLACIAL DRAINAGE OF LAKE REGION, ACCORDING TO PROF. J. W. SPENCER.

ley, perhaps by way of Chicago or Kankakee. The northern part of the Michigan basin communicated with the Huron river system through a now buried channel in the Mackinac Straits and the southern part through the valley of Grand River across the Michigan peninsula to Saginaw Bay. From the Mackinac Straits the Laurentian River passed through the Huron basin, where it was joined by the southwestern Huronian River from Saginaw and a southern branch. Having rounded Cabot's Head it then followed the western side of the Georgian basin, crossing the Canadian peninsula by way of Lake Simcoe and entering the Ontario basin a little west of Toronto. From its southern end the Huron basin also drained through the valley of Sable River by way of London into the Erie basin a little east of Port Stanley. The Erigan River, which drained this basin, received several minor tributaries from the south and possibly a larger stream from the Alleghany valley by way of Dunkirk, N. Y. Bending north through the valley of Grand River, it entered the Ontario basin, where it joined the Laurentian River, which may have had its outlet through the St. Lawrence valley (Spencer); or, perhaps, emerged through the Mohawk valley into the Hudson River (Newberry).

At the beginning of the glacial epoch, local glaciers moved down from the Laurentian highlands through the old river valleys, enlarging and deepening them. When, gradually, these glaciers united into one large ice sheet descending from Canada, all rivers which were flowing north had their courses reversed; and when, in the course of time, the drainage of the lake region became obstructed by the advancing glacier blocking the outlets of the Laurentian River (St. Lawrence or Mohawk) the water arose and formed a series of huge lakes, which through the valleys of the Fox and Wisconsin and the Illinois River drained into the Mississippi, and through those of the Wabash and the Scioto, Muskingum and Beaver Rivers into the Ohio. Advancing further south, the great glacier covered the whole lake region with an ice sheet, which in the eastern states was perhaps 1,500 to 2,000 feet thick and in western states may have been considerably more, possibly over 10,000 feet thick (Wright.) Then the lake basins were carved out of the rock, the erosive power being apparently greatest a few hundred miles back of the margin of the ice (Gilbert). The amount of the erosion was determined chiefly by the pre-glacial shape of the surface, the thinner ice sheet over the high lands having less power than the thick ice in the valleys, and the result therefore being a further deepening of the latter. At first stopped by the Alleghanies and Ohio highlands, the glacier flowed westward through the Ontario and Erie basins, as indicated by the striae on the islands off Sandusky, O.; when, during the height of the ice age, it overtopped the watershed south of Lake Erie, it moved southward to the Ohio River. Thus the two lakes got their peculiar oblong shape with a profile more abruptly descending from the east and gradually rising to the west. Similarly were Lakes Huron and Michigan shaped by the southward movement of the ice with a relatively steeper slope from the north and more gradual ascent to the

south. Through Green Bay the ice moved west, as indicated by the Kettle range; from Keweenaw Bay it advanced south, and from the west end of Lake Superior west to Lake Minnetonka and the Mississippi. Thus, Lake Superior was also eroded by the glacier, as well as, farther north, in Canada, Lakes Winnipeg, Manitoba, Garibou, Athabasca, Great Slave and Great Bear Lake; most of the smaller lakes, however, occupy kettle-holes. Of the same glacial origin, eroded in pre-glacial valleys, are lakes in other parts of the world, such as the north-Italian Lago Maggiore, Como, etc., and the Swiss Lakes Constance, Zürich, Lucerne, Neuchatel and Geneva (Ramsay), in which the glacier moved from east to west and which is therefore deepest in its eastern end.

When, with the return of milder seasons, the ice began to retreat and the land, which may have been depressed by the weight of the enormous ice sheet, began to rise again, local glaciers still continued excavating the basins of the Great Lakes, moving nearly westward through the Erie and Ontario basins. An ice barrier in the Ohio River near Cincinnati may have caused its water, vastly increased with that of the melting ice, to rise about 550 feet and form a large temporary lake, which has been called Lake Ohio, and the terrace deposits of which are still traced about 1,000 feet above tidewater. At the foot of the retreating ice a lake was naturally formed by the water from its melting. Covering at first only the Maumee valley and the west end of the Erie basin, it gradually expanded to include part of the Huron and Ontario and the whole Erie basin until, when the glacier had retreated about 120 miles and still filled the valleys of the Mohawk and St. Lawrence Rivers, the large Lake Erie-Ontario covered about 8,000 sq. miles, its water being raised about 220′ above the present level of Lake Erie, and discharging through the Wabash River to the Mississippi. At the south end of the Michigan basin another smaller lake was formed, discharging through the Desplaines and Illinois Rivers. As the ice retreated to the north these lakes gradually expanded, uniting into one large sheet of water, as indicated by terraces above the Maumee beach, covering the lower and part of the upper peninsula of Michigan and joining the lake which was formed at the west end of the Superior basin and discharged through the St. Croix River into the Mississippi.

Retreating still farther, the melting ice formed another lake at the headwaters of the Red River of the North, the immense Lake Agassiz, which was perhaps 230 miles broad by 550 miles long and covered an area of over 100,000 sq. miles, including the basins of Lake of the Woods, Winnipeg, Saskatchewan, etc. It drained by "River Warren" through Brown's valley between Lake Traverse and Big Stone Lake into the Minnesota and Mississippi, and was traced by Warren Upham* by three beaches (Herman, Norcross, Campbell), the upper one of which (Herman) is 85 feet above the valley.

During these closing times of the glacial epoch a subsidence of

*Ann. Rep. of Geol. Surv. of Canada, 1888-89.

the continent may have caused the waters of the Atlantic to flow up the valley of St. Lawrence to Kingston and of Ottawa to Arnprior, flooding the Hudson and Lake Champlain valleys so as to leave New England an island. Hence arctic, marine mollusks are found in such great quantities in the Champlain clays of the Champlain, lower St. Lawrence and Ottawa valleys. The "Warren Water," which covered all the lake basins from Superior to Ontario, was 400 miles broad and 600 to 700 miles long and bordered by the "Maumee Beach." It may have been an arm of the sea and the different beach lines therefore of marine origin; a marine fauna might perhaps have been excluded by the ice-cold fresh water flowing down from the melting glacier. Or it was a glacial lake, with one outlet through the Wabash, another through the Desplaines and Illinois, and a third, perhaps, through the St. Croix River. Its water was gradually lowered until temporarily held back by ice dams, or a regional uplift of the country took place, by which, perhaps, its northern part or the Superior, Nipissing and the north end of the Huron basin was lifted some 400 feet. Thus, a new shore line was formed, to be deserted in its turn when the water had found a way through the old outlets, or through new, and gradually was lowered, until temporarily retained again sufficiently long to form another lower beach. To each new shore line corresponded a changed appearance of the Warren Water, as it was shrinking more and more, bordered sucessively by the "Ridgeway Beach," "Arcona Beach" and "Forest Beach" until at last it was broken up into the Algonquin and Lundy Gulfs, the latter

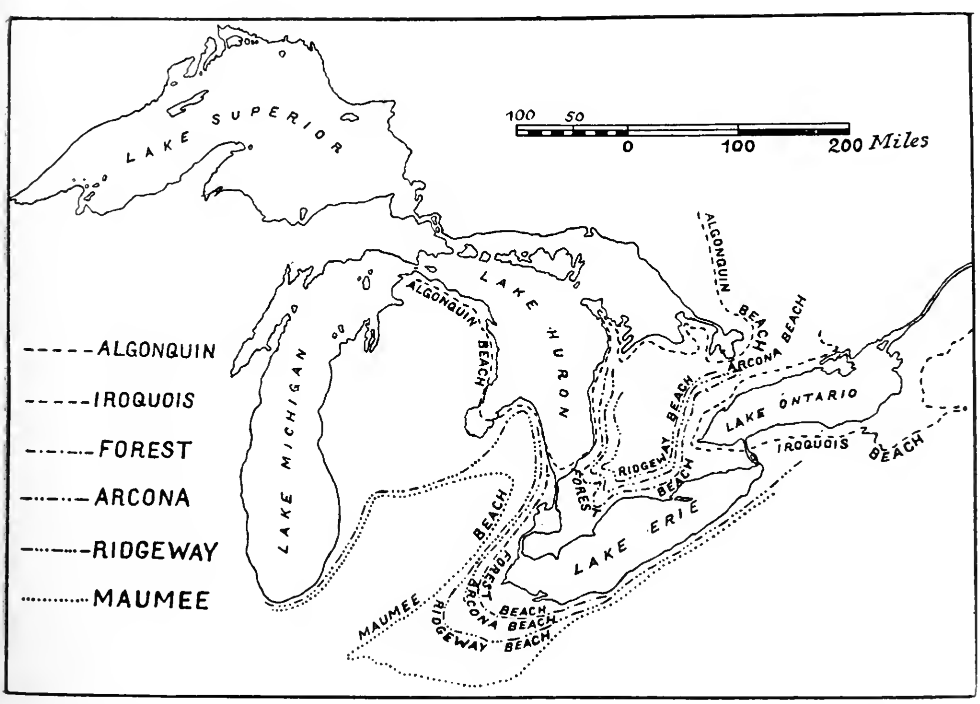

FIG. 96. ANCIENT SHORE LINES ACCORDING TO PROF. J. W. SPENCER.

of which occupied the Erie and Ontario basins (Spencer*). At its final dismemberment, which was partly due to a differential uplift, the waters of the Superior, Michigan and Huron basins were contained by the "Algonquin Beach" and those of the Ontario basin, which were lowered several hundred feet, by the "Iroquois Beach." The water of the Erie basin was also lowered and, finding the old pre-glacial outlet to the north and the several later outlets to the Ohio River to the south all filled with drift, it excavated the Niagara River and the falls at Queenstown had their birth. At first the descent was 200 feet, but after another subsidence of the Ontario basin had taken place, followed by a partial upheaval, it was about 320 feet.*

The "Iroquois Water"* was at first perhaps a bay of the ocean, which Spencer likens to the Gulf of Obi, in Siberia, into which so much fresh water is discharging that it renders the Arctic Sea quite brackish for a considerable distance out. The Iroquois Beach was originally built at sea level, but underwent later, with the whole region, an uplift and tilting by which the bay was changed into a lake, discharging through the St. Lawrence or, if that outlet was blocked by an ice barrier, through the Mohawk River or Lake Champlain (Gilbert). "Lake Algonquin"† covered the three upper lake basins and its water stood at one time perhaps 300 feet above the Iroquois Gulf. The south end of the present Lake Michigan was dry and in Lake Superior the water was very shallow. At the south end of Lake Huron, a few miles north of what is now the entrance to the St. Clair River, the old Algonquin Beach passes submerged from Canada to Michigan. There was at first an overflow by way of Balsam Lake and the Trent valley, but later on it was by way of Lake Nipissing and the Ottawa valley, forming a broad and deep strait between the Algonquin and Iroquois basins. This outlet may or may not have been barred by an ice dam for some time.

At the same time as the water of the Algonquin Lake ran off, an uplift of the whole region took place and more and more of the land appeared. There were periodical standstills in this lowering of the water as beaches, notably around the Georgian Bay and in the Iroquois basin, show; but gradually the lake got dismembered and Lakes Superior, Michigan, Huron and Georgian Bay had their birth. By a north-eastward warping of the earthcrust, Lake Michigan was tilted over 400 feet in a length of somewhat over 300 miles. At first the outlet of these three upper lakes was through Lake Nipissing and the Ottawa River, and only the waters of Lake Erie were discharged through Niagara River; but by a differential uplift the Nipissing outlet was closed, the beaches at the south end of Lake Huron were submerged and the water flowed through the St. Clair and Detroit Rivers into Lake Erie, whence the Niagara River hence-

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*J. W. Spencer in Am. Jour. of Science and Arts, 140, 1890 and 141, 1891; Proceed. Roy. Soc. of London, vol. 56, 1894; Appleton's Pop. Science Monthly, 49, 1896.

†J. W. Spencer in Am. Jour. of Science and Arts, 141, 1891.

forth had to carry the drainage of the four upper lakes. Meanwhile, the regional uplift had also closed the old Mohawk outlet and gradually reduced Lake Iroquois to the present Lake Ontario, discharging, as now, through the St. Lawrence River.

That an uplift of the lake region has taken place since the close of the drift period and the formation of the Warren Water is proved by the depth of till down to the old rock bed in the valleys of affluents to the lakes and old outlets from them, such as the rivers in Ohio and Michigan, the Desplaines River in Illinois, etc. That it was a differential uplift is evident from the nature of the old beaches, which also show that the rate of tilting differed in different localities and at different times. Most of them rise to the north and east, and the greatest tilting seems to have taken place after the Algonquin and Iroquois episode, diminishing gradually from then, as seen by the gentler rise of the beaches below the Iroquois beach. The Maumee Beach is at Columbia, Mich. 683′ and at Cleveland, O. 786′ above the sea; it rises across the Michigan peninsula about 1 foot per mile, hardly anything south of Lake Erie and 2 ft. per mile east of it. The Ridgeway Beach is near Chicago 542′, at Cleveland, O. 743′ and at Hamburg, N. Y. 870′ above the sea; on the Canadian side its elevation is at Lucknow 989′, at Komoko 848′ and at Mono Mills 1,400′. The Arcona Beach is at Goodells, Mich. 697′, at Cleveland, O. 708′ and on the Canadian side at Walkerton 944′, at Arcona 789′ and at Stouffville 1,175′ above sea level. The elevation of the Forest Beach is at Port Huron, Mich. 665′, at Cleveland, O. 673′ and at Crittenden, N. Y. 860′, and in Ontario at Bowie 910′, at Forest 720′ and at Stouffville 1,025′; its rise to the northeast is at the east shore of Lake Huron 1.5 ft. per mile and at the northwest end of Lake Ontario 3 ft. per mile. The Algonquin Beach is on the Canadian side at St. Clair River 562′, at Kirkfield 875′ and at Burk's Falls 1,171′ above sea level; it rises at the east shore of Lake Huron 1.33 ft. per mile, at the end of Georgian Bay 3 ft. per mile and at Burk's Falls 4.1 ft. per mile in a northeasterly direction. The Iroquois Beach is at Trenton, Ont., elevated 682′, at Hamilton, Ont. 363′, at Cleveland, N. Y. 484′ and at Fine, N. Y. 972′; it rises to the northeast at the northwest side of Lake Ontario at a rate of 1.60 ft. per mile and at the east side of the lake 3.5 ft. per mile at Cleveland, 5 ft. at Watertown and 6 ft. at Fine. If this beach was formed at ocean level its elevations indicate the total uplift of the region.

The old beaches of the extinct Lake Agassiz do also rise to the north; but no such movements of the earthcrust are at present noticeable in the lake region or they must be extremely slow (Gilbert), and it is doubtful whether a terrestrial uplift per century of 1.25 ft. in the Niagara district, 2 ft. at the east side of Lake Huron, 2.5 ft. at the outlet of Lake Ontario and 4 ft. north of the Adirondacks (Spencer) can be detected. Anticosti Island, in the Gulf of St. Lawrence, is said to be rising. According to Spencer the northeastern rims of the lakes are slowly rising, causing the lakes to flood their southwestern shores. He therefore predicts that in 5000 years the northeast end of Lake Erie will be so high that the water will be turned from Niagara River and find its outlet to the Mississippi.

Opinions are conflicting in regard to the time which has elapsed since the close of the glacial epoch and since the birth of the Great Lakes in their present shape. The annual retrogression of the Niagara Falls gives a fair estimate of their age, even though it must be remembered that the erosion may have been less than at present if, for a time, only Lake Erie discharged that way. It measures, therefore, not necessarily the time since the lakes found their present drainage nor the length of the post-glacial period, inasmuch as the water may have flowed through the Lake Nipissing and Ottawa valleys after the ice had receded from the site of Niagara River. It is also possible, as suggested by Pohlman, that the present bed was partly excavated by a pre-glacial river or by the Tonawanda and Chippeway Creek, an old outlet of which is traced from the Whirlpool to Lake Ontario. The recession of Niagara was by Desor given as 1 ft. in 100 years, by Lyell as 1 ft., by Blakewell as 3 ft., and by Gilbert as 5 ft. per year. Woodward found it to have been from 1842 to 1886 about 2½ ft. per year at the Horseshoe Falls, and continued observations give 2.18 ft. for these and 0.64 ft. for the American Falls, from which it may be inferred that possibly the latter may disappear in the course of 3,000 years and all the water pass over the Horseshoe Falls when they have receded above Goat Island. The total recession from Queenston, where the river cuts through the escarpment, to the present falls is about 7 miles. Hence, according to Lyell's estimate, the age of the falls is 37,000 years, whereas Ellicott, in 1790, estimated it to be 55,000 years and Gilbert makes it 7,000 years. This latter figure agrees with the 7,800 years that Winchell found as the age of the Falls of St. Anthony, at Minneapolis, and the 7,500 years which Andrews, from consideration of the 5-6 ft. annual rate of erosion of Lake Michigan, deduced as the age of the lake basins. Spencer,* however, assuming 4.175 and 0.64 ft. as the modern annual recession of Niagara Falls, ascribes to them an age of 28,000-31,000 years and to the river perhaps 1,000 years more. According to his views, Lake Erie drained through Niagara River for 20-23,000 years before, about 8,000 years ago, the other three upper lakes sent their overflow the same way and the St. Clair and Detroit Rivers were born. The water fell at first, for 17,000 years, only 200 ft., then for 10,000 years 420 ft. in three cascades, which were subsequently united into one, and finally, for 3,000 years, 320 ft., as at present. The beginning of the lake age, i. e., the post-glacial period, he estimates at 64-80,000 years ago.

HYDROLOGY OF THE LAKE BASINS.

According to the geological sketch outlined in the preceding pages, the Great Lakes owe their origin to glacial erosion, the deposits of drift—which confined their basins and raised their levels by burying old outlets—and warpings and differential uplifts of the earthcrust. In their present shape they cover about one-third of

*Proc. Roy. Soc. of London, vol. 56, 1894.

their total drainage area and are fed by only short and relatively unimportant streams. The figures contained in the following table give the dimensions, areas, depths, levels, etc., of the chain of lakes and connecting rivers:

	Length. Miles.	Average width. Miles.	Maximum width. Miles.	Shoreline. Miles.	Water area (including islands). Sq. miles.	Average depth. Feet.	Maximum depth sounded. Feet.	Surface above tide-water. Feet.	Deepest point above tide-water. Feet.	Water volume. Cub. miles.	Land area of water-shed. Sq. miles.	Aggregate water and land area of water-shed. Sq. miles.
Lake Superior	390	70	160	1300	31200	475	1008	602	—406	2800	51600	82800
St. Mar y's Riv	53 40	2½ 2	5 4	100	200	..	53	....	....	....	800	1000
Lake Michig'n	335	58	85	875	20200	335	870	581	—289	1290		
Green Bay. ..	115	15	21	260	1700	95	144	581	+437	30	37700	60100
Mackinac S't..	30	16	23	60	500	75	234	581	+347	7		
North Chann'l	110	12	18	220	1400	70	240	581	+341	20		
Lake Huron..	250	54	100	725	17400	210	702	581	—121	650	31700	55700
Georgian Bay.	120	40	58	390	5200	170	462	581	+119	170		
St. Clair's Riv.	35	1	...	70	30	..	....	....	....	....	3800	3830
Lake St. Clair.	19	25	29	90	410	..	21	575	+554	1	3400	3810
Detroit River.	27	2	3½	54	60	..	....	....	....	....	1200	1260
Lake Erie....	250	40	58	590	10000	70	204	573	+369	130	22700	32700
Niagara River	34	1	2	70	60	..	....	....	....	....	300	360
Lake Ontario.	180	40	58	600	7300	300	738	247	—491	410	21600	28900
St. Lawr'ce R.	760	20	95	....	....	..	....	....	....	....	......	......
				5404	95660					5508	174800	270460

The table shows that without including St. Lawrence River, the lake system has a total length of shore line 5,400 miles, a total water area 95,700 sq. miles, a total land area drained 174,800 sq. miles and, therefore, a total watershed 270,500 sq. miles.

Belonging to the same drainage system and of the same origin, the lakes differ in some respects, as might be expected from the great range of territory they cover and the differences in geological structure of their shores.

Lake Superior is a little larger than Victoria Nyanza, and therefore the largest fresh water lake in the world, even though its size is less than one-fifth of that of the Caspian Sea. It is encircled by rocky cliffs, except at the mouth of some rivers, especially at its west end, where sandy beaches occur and bluffs of red clay are seen, and on the south shore, where from Point au Sable to Whitefish Point, sand dunes and hills rise 3-500 ft. Along the north shore from Duluth, barren greenstone and porphyry cliffs rise 800-1,000 ft.; from the Palisades the basaltic rocks round Thunder Bay, reaching, at Thunder Cape, a height of 1,350 ft.; and at Otter Head the cliff is 1,000 ft. high. On the south side the cliffs consist of Lake Superior sandstone, and rise at the Pictured Rocks 50-200 ft. On Isle Royal the eruptive rocks are 580 ft. high, on Isle St. Ignace 1,250 ft., on Michipicoten 937 ft., but on the Apostle Islands the clay and sand-

stone cliffs are lower. The main tributaries are St. Louis, Pigeon, Kaministiquia, Nipigon (from the lake of the same name), Pic and Michipicoten River. Many of the streams are lacustrine emissaries and as such bring down only little sediment. Mud deposited on top of the drift that covers the bottom of the lake consists of sticky red and blue clay with innumerable shells. Of the 20½ ft. difference between the levels of Lakes Superior and Huron, 17½ ft. come on the Sault, which is formed in St. Mary's sandstone, and the balance on the rapids of St. Mary's River.

Lake Michigan has mostly low and sandy shores with a gradual slope. On its east shore and around its south end, the sand forms dunes which are generally bare and reach a height of 150-250 ft. The Lower Peninsula is considerably higher in its northern than in its southern part, and the bluffs rise therefore from 40-60 ft. to 200 ft., as on the Manitou Islands, and 500 ft. at the Sleepy Bear Point; they consist of gravel and sand, sometimes connected into conglomerates by carbonate of lime. On the southwest shore, lower sand hills are found and at a distance of until a mile from the waters edge the high plateau forms 10-30 ft. high bluffs. At the north end of the lake the shores are more rugged and irregular, and at Robison's Folly and St. Ignatz' Point the cliffs consist of dolomites and breccia of the Helderberg group. There the islands are found: Washington, Manitou, Beaver, etc. Tributaries are: Escanaba, Menominee, Fox, St. Joseph, Kalamazoo, Grand and Manistee Rivers. The many lakes near the shore, mostly of an elongated form, are peculiar to the east side, particularly around Traverse Bay, and are supposed to be of glacial origin. Lake Michigan is believed to move slowly westward, encroaching upon its western and building up its eastern shores. This encroachment and undermining of the banks seems to be most rapid near Racine, Wis., where it is 3.33 ft. per year; in Milwaukee County it is 2.77 ft. per year, but in northern Illinois it is rather an accumulation that takes place. The eroded material settles down as a sediment on top of the sheet of glacial drift that covers the bedrock, which therefore, perhaps, is 100-200 ft. below the bottom of the lake.

Lake Huron, with Georgian Bay, Saginaw Bay and Thunder Bay, and its many large and innumerable smaller islands, is more irregular in form and more varied in nature than any of the other lakes. Its western shores are, like the eastern shores of Lake Michigan, lower and more gradually rising in the southern than in the northern part, and consist of clay and sand bluffs, with finely timbered terraces. The northern shores are more rugged and rocky, presenting generally an undulating country with rounded and timbered hills, 400-700 ft. high. Between Lake Penage and Spanish River quartzite rocks are predominating, rising in the LaCloche Mountains 755 ft., and in Northeast Hill 1,080 ft. above Lake Huron. Around Georgian Bay the rocks are generally lower, rising occasionally at the south end 500 ft., and, in the Blue Mountains, 1,070 ft., but the shores are very irregular, carved into deep inlets and fiords. The

east shore from Cape Hurd is low with ledges of rock, alternating with cliffs of clay and boulders, and sand beaches and dunes. Grand Manitoulin, Great Cloche, Cockburn, Drummond, St. Joseph, Bois Blanc and Mackinac Islands have rugged and rocky shores, mostly consisting of silurian and devonian limestones and sandstone. Tributaries are: French River, from Lakes Nipissing and Tamagamingue; Maganatawan; Severn, from Lake Simcoe; Saugeen, Black River, Saginaw, Au Sable, etc. The bottom of the lake is covered with drift and clay; at St. Martin's and Goose Islands, however, marls and gypsum of the Onondaga salt group may be seen through the water, and off Thunder Bay Island is a subaqueous cliff of Corniferous limestone, nearly 100 ft. deep.

The 8½ ft. difference between the levels of Lakes Huron and Erie is distributed between St. Clair River with a descent of 6 ft., and Detroit River with a descent of 2½ ft. When the former, in which the current is 3½-4 miles an hour, enters Lake St. Clair, it deposits sand and forms the flats. Tributary to the lake is also Thames River. Its shores are low, covered with fields of wild rice.

Lake Erie is, like Lake Michigan, of a rather regular form with few indentations. Its shores rise quite boldly, consisting of sand and, in a predominating degree, clay; occasionally rock ledges appear. Where the lake eats away the land, as between Cleveland and Fairport, the bluffs reach a height of 103 ft. Only at some distance from the shore is the land timbered, except at the west end, where a white sand forms the beach. The exposed rocks of Niagara limestone on the islands off Sandusky, between Point Marblehead and Pelée, show remarkably deep and continuous glacial grooves, which indicate four different ice movements. The basin of the lake forms three terraces; the western, which is 25-40 ft. deep, is separated by the just-mentioned islands and promontories from the middle portion, which is 40-85 ft. deep, and which again is separated by a line from Long Point Island to Presque Isle at Erie from the eastern portion, in which the depth is 70-180 ft. The main tributaries are: Huron, Maumee, Sandusky, Cuyahoga, Grand River, etc. At their mouths deltas are forming and the lake is gradually filling up with their alluvial deposits. Its bed consists of sand, clay and mud, and the rock is covered with 100-200 ft. of drift.

The total descent from Lake Erie to Ontario is 326¼ ft. From Buffalo to below Grand Island, at the upper end of the rapids, Niagara River descends 12¼ ft., in the rapids above the falls 44 ft., at the falls 160 ft. (Horseshoe Falls, 158 ft.; American Falls, 167 ft.), in the rapids above the suspension bridge 17 ft., in the rapids above Lewiston 91 ft., and from there to Fort Niagara 2 ft. Below the falls the river runs between vertical limestone cliffs 200 ft. high. Its tributaries are Tonawanda Creek and Chippewa River.

Lake Ontario has generally low, or only moderately high, shores of clay and gravel and sand. East of Toronto they rise somewhat higher and loftier, subsiding again gradually towards the Prince Edward peninsula, and remaining low, in many places marshy, until the entrance to the St. Lawrence River. The ridge of hills, that

separates the two terraces by which the Canadian tableland rises from the lake, begins at the Bay of Quinte at a distance of 8-9 miles from the shore and runs west, receding from the lake until opposite Toronto it is 24 miles inland. Another ridge rounds the west end of the lake and the Burlington Bay, and is continued along the south shore at a distance of less than 4-8 miles from the lake, passing by Queenston, where the Niagara River breaks through it, to Lockport and Rochester, where the Genesee River forms its three falls. The Thousand Islands at the eastern extremity of the lake and the upper part of St. Lawrence River differ greatly in size and appearance, some presenting only bare masses of silurian rocks and others being thickly wooded. Tributaries are: Genesee, Oswego from Oneida Lake, and Trent River.

Measurements of the discharges of the lakes through their connecting rivers and St. Lawrence must naturally vary with the stage of the water, wind direction, etc. As averages have been given for St. Mary's River 88,000 cub. ft. per sec., St. Clair 215,000, Detroit 245,000, Niagara 260,000 and St. Lawrence 300,000. The corresponding mean velocities and maximum velocities in miles per hour are for: St. Mary's River 0.66 and 1.30, St. Clair 2.39 and 3.09, Detroit 2.04 and 2.71, Niagara 1.54 and 2.32, St. Lawrence 0.65 and 1.00.

Major Ruffner summarizes in a recent article* the various discharge measurements of Niagara. Those taken in 1891-92 gave for a rise of 1.85 ft. on the Buffalo gauge, an increase of the discharge from 191,822 c. f. s. to 239,677 c. f. s. Near mean level of Lake Erie a change of about 21,000 c. f. s. in the discharge corresponds to a change of 1 ft. on the Buffalo gauge.

It has been claimed that subterranean streams partially feed, connect and drain the lakes.** According to this view, Lake Huron connects directly with Ontario, Lake Michigan discharges at its south end into the Kankakee and Illinois River and there is a subterranean passage from Lake Superior to Lake Geneva and other lakes in Wisconsin. This seems, however, to be mere fiction, not based upon real facts.

The currents in the lakes † have been studied by the Weather Bureau in 1892-3 by means of the movements of bottles. There is in all of them a main current toward the outlet, hugging the southern shores of Superior, eastern shores of Michigan, western shores of Huron and southern shores of Erie. Surface currents are due to prevailing winds, and therefore generally easterly or northeasterly; others are caused by differences in barometric pressure. Return currents result from the insufficiency of the outlets for the escape of the water. In Lake Ontario no return current is perceptible, in Lake Erie it follows the north shore and forms eddies around the

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*Eng. News, 32, 1894.

**Scribner, 11, 1876.

† Sailing Directions for the Lakes, parts I-IV., published by Hydrographic Office, 1894.

islands, in Lake Michigan one whirl is formed around Beaver Island and another at the south end, the current along the west shore, south of Racine, being south and north of it north. The velocity of the lake currents, which are particularly noticeable in Lake Erie on account of its shallowness, varies from 4-12 knots a day.

On the annexed map of the Great Lakes, which is constructed—on the Mercator projection—from the recent charts of the Hydrographic Office, depths are indicated by contour lines. Mr. Schermerhorn* has called attention to the fact that the line of deepest water does not coincide with the middle line of the lakes, but approximately with that of their drainage basins, the centers of which, except in Lake Erie, coincide with the points of greatest depth. On account of its shallowness the water in Lake Erie has a green hue, whereas in the deeper lakes, particularly Superior and Huron, it is deep blue, as that of the ocean. Its purity and clearness are remarkable. A white object one sq. ft. in area may be seen at a depth of 40 ft. below the surface; and Lake Superior water is used as distilled water in chemical laboratories in Michigan. By evaporation of 1,000,000 parts of water, taken at Grand Marais, a solid residue of about 46 parts (by weight) was found, consisting of:

Sodium sulphate, $Na_2\ SO_4$	0.6
Chloride of sodium, $Na\ Cl$	2.1
Sodium carbonate, $Na_2\ CO_3$	0.5
Potassium carbonate, $K_2\ CO_3$	1 9
Potassium nitrate, $K\ NO_3$	0.2
Magnesium carbonate, $Mg\ CO_3$	9.1
Calcium carbonate, $Ca\ CO_3$	30.8
Silica, $Si\ O_2$	0.5
$K\ NO_2$, $Li_2\ CO_3$, $Fe_2\ O_3$, $Al_2\ O_3$	traces
Total	45.7

Lake Michigan water contains in 1,000,000 parts about 145-150 parts (by weight) of solids; the chemical composition of which for water taken at Chicago is:

Suspended matter, $\left\{\begin{array}{l}Si\ O_2\\ Ca\ SO_4\\ Ca\ CO_3\end{array}\right\}$	13.500
Free Ammonia, NH_4	0.007
Albuminoid Ammonia	0.089
Chlorine	2.113
Potassium sulphate, $K_2\ SO_4$	4.848
Sodium sulphate, $Na_2\ SO_4$	3.855
Sodium phosphate, $Na_3\ PO_4$	0.034
Magnesium carbonate, $Mg\ Co_3$	37.724
Calcium carbonate, $Ca\ CO_3$	76.492
Calcium sulphate, $Ca\ SO_4$	5.465
Ferro carbonate, $Fe\ CO_3$	0.497
Alumina, $Al_2\ O_3$	0.034
Silica, $Si\ O_2$	5.242
Total	149.900

*Am. Jour. of Science, 133, 1887.

In samples taken at Milwaukee the sulphates of sodium and potassium were found replaced by chloride of sodium, i. e., common salt (6.000 parts). In water from the deepest part of Lake Superior chemical analysis failed, however, to indicate the presence of larger quantities of salt.

The temperature of the water in the deeper part of the lakes differs little from the mean annual temperature of the air, the variation with increased depth being quite insignificant for points more than 400 ft. below the surface. In Lake Superior the temperature of the body of the water never rises above 46°F.; at depths over 200 ft., it varies but slightly from 39°F., going sometimes as low as 33°F.; the same applies to Georgian Bay. In Lake Michigan at the Chicago water in-take crib, the annual average temperature of the water was 47°F. when that of the air was 48°F.; the total variation from the minimum (February) to the maximum (July, August) monthly temperature being for the water 34 and for the air 52 degrees. For Lake Huron during summer the temperature of the air was 64°F., of the water at the surface and at a depth of 300 ft., 52°F., while at a depth of over 600 ft. it was 42°F. For Lake Erie in August the temperature at noon of the air was 76°F., of the water at the surface 73°F., and at the bottom, at a depth of 80-100 ft., 53°F.

During 4-5 months navigation is closed on account of the freezing up of the lakes. It is, however, very unusual that they freeze in the middle. In 1826 the ice on Lake Ontario was 23½ inches thick, and in 1843 Lake Superior was completely frozen over. Only the northern part of Lake Michigan is ice-bound in winter; the lake south of Milwaukee never is. Lake Erie, on account of its shallowness, usually freezes up before and remains frozen longer than most of the other lakes. Both St. Mary's and Detroit River are frozen over in winter; so are Mackinac Straits and the Welland Canal. According to observations extending through 7-20 years, the dates of closing and opening navigation or the total number of days closed average* for:

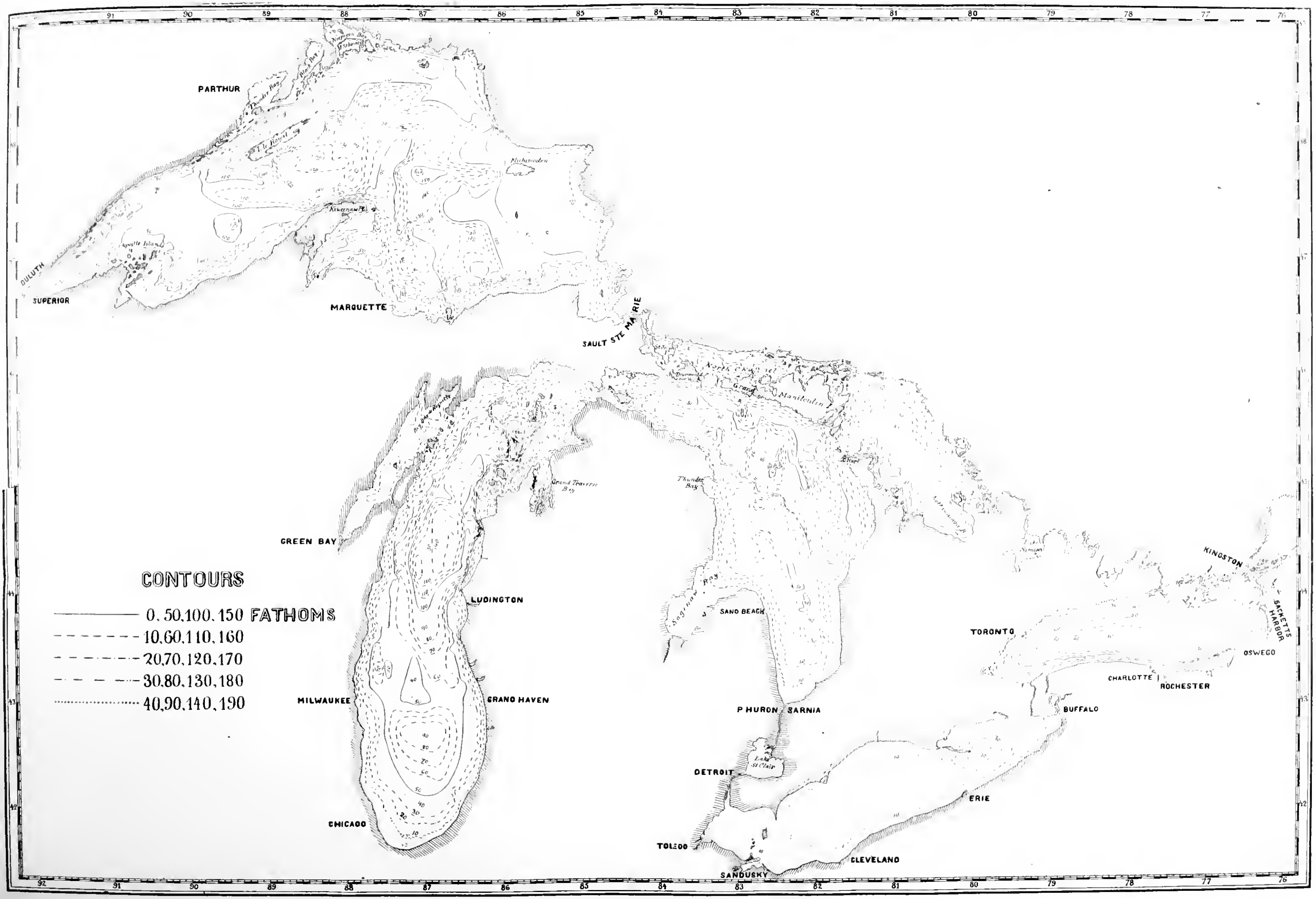
Duluth	Dec. 26—May 7,	or 133	days.	
St. Mary's Canal	Dec. 3—April 29,	" 148	"	
Straits of Mackinac	Dec. 3—April 21,	" 140	"	(?)
Milwaukee	Dec. 5—March 15,	" 100	"	(?)
Detroit River	Dec. 2—April 2,	" 122	"	
Buffalo	Dec. 20—April 16,	" 126	"	(?)
Welland Canal	Dec. 9—April 24,	" 137	"	
Montreal	Dec. 15—April 24,	" 131	"	

Thus, Lake Superior is closed 4½-5 months, Michigan 3½-4½, Huron, Erie and Ontario 4-4½ months.

Mostly due, perhaps, to the different temperatures of their water, the lakes differ somewhat in their fauna. This applies particularly to Lake Superior and Georgian Bay, the mean temperatures of which are nearly 20 degrees less than of the other lakes. Besides fishes common to all the lakes, such as perch, bass, pike-perch, bream,

*Lakes and Gulf Waterway, by L. E. Cooley, Chicago, 1891.

CHART OF THE GREAT LAKES



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bullhead, sculpin, darter, sheepshead, minnow, dace, sucker, pike or muskellunge, catfish, lake t[illegible]ut, whitefish, lake herring, garpike, etc., the siscowet (salmo siscowet), Lake Superior whitefish, horned dace, etc., are peculiar to Lake Superior; the inland alewife (clupea chrysochloris) and hickory shad (dorosoma cepedianum) occur in Lakes Michigan and Erie; the river herring or alewife (clupea vernalis) in Ontario; the deep-water sculpin (triglopsis Thompsonii) in Michigan and Ontario, etc. The latter is ordinarily considered a marine form; and marine crustaceans (mysis) have been found in the stomachs of whitefish and were brought up by dredgings in Lake Michigan from a depth of 3-400 ft.* The water being fresh at that depth as at the surface, these varieties must have adapted themselves to the changed conditions, if—as it would be rash to conclude, however—they are remnants from a time when the ocean reached to the heart of the continent.

It is evident that the vast water expanse of the Great Lakes exerts a modifying influence upon the climate of the whole region. The diurnal range of variation of the atmospheric pressure is diminished (0.046 ins. at Chicago) and the annual range of temperature is at least 5-10 degrees F. less than at points fifty or a hundred miles inland. The autumns and winters are milder and springs and summers cooler. Lying between Isothermals 44° and 52°F., the lake basins have an annual mean temperature of about 45°F., and a precipitation of about 32″ rain and melted snow. The 32″ isohyetal curve has an almost due easterly course along the southern shore of Lake Superior and the northern shore of Lake Huron, the 26″ curve entering the United States a little northwest of Superior. For the different basins the precipitation averages as follows: Superior 29″, Michigan 32″, Huron 30″, Erie and Ontario 34″. For a number of representative cities around the Great Lakes the mean annual temperature and annual precipitation, mostly for the last 14–22 years, are contained in the following table.**

	Temperature annual mean degrees Fah.	Precipitation annual Inches.		Temperature annual mean degrees Fah	Precipitation annual Inches.
Port Arthur.	33.4	24.0	Detroit, Mich.	48.3	32.6
Duluth, Minn.	39 2	32.0	Toledo. O.	49.6	31.7
Marquette, Mich.	40 6	32.5	Sandusky, O.	50.4	35.5
Sault Ste. Marie, Mich	39.1	34.5	Cleveland, O.	48.9	37.7
Milwaukee, Wis.	45 2	32.2	Erie, Pa.	48.9	41.7
Chicago. Ill.	48.7	35.0	Buffalo, N. Y.	46.4	38.2
Grand Haven, Mich.	46.3	35.6	Toronto.	43.4	30.8
Alpena, Mich.	41.3	36.4	Rochester, N. Y.	47.3	35.2
Port Huron, Mich.	45.1	32.2	Oswego, N. Y.	46 5	35.0
Saugèen.	41.2	34.4	Kingston	42.5	33.9

The annual variation of monthly mean temperatures is greatest for: Port Arthur, 63.0 deg., Duluth 56.8, Kingston 53.0; least for:

*Am. Naturalist, 4, 1870.
**From data furnished by U. S. Weather Bureau.

Erie 43.3, Grand Haven 43.4, Buffalo 44.6, Cleveland 44.8; and between 45 and 50 deg. for the remainder. The number of rainy days (rainfall more than 0.01 inch) is around Lakes Erie and Ontario 170 per year, and the probability of a rainy day in the lake region is in winter 0.6. Of thunderstorms about 20 occur annually. The evaporation, if taken as 50″ per year, amounts to 11.1 billion cub. ft., or 75.5 cub. miles, from the total water surface of the lakes. A notable feature is the regularity of the lake breezes which blow toward land during daytime—in the summer usually from 8-10 a. m. to sunset—and the land breezes toward the lake during night—in summer from 9-10 p. m. to sunrise. The beautiful autumnal sunsets seen in the lake region during September and October, with their rich hues of gold and crimson are thought to depend, to some extent, on electrical conditions of the atmosphere, but to be due mostly to reflection from the lake surfaces and refraction. Differences in temperature of air and water produce the optical illusion, mirage.

Of more interest than any other phenomena connected with the Great Lakes are, however, the variations of their water-levels and their periodical increase and decrease. Such variations are [1]daily, caused by lunar tides, [2]annual, depending upon seasons and differences in precipitation and evaporation, [3]secular, due to changes of climate and nature, subsidence and uplift, erosion and filling up of channels, etc.; or they are caused by [4]winds and differences in atmospheric pressure, [5]waves, raised by the wind or [6]seiches, due to changes in atmospheric pressure, volcanic eruptions or unknown causes.

There are tides in every pond, be it ever so small. That there are tides in the Great Lakes is therefore certain and, insignificant though they are, they are still preceptible when automatic gauge records are subjected to harmonic analysis. Dr. Young, in his theory of lake tides, compares them to motions of a pendulum, the level at the centre of the lake not undergoing any variation; from the depth and area (width) of the basin he thus determines the amplitude and period of the oscillation. At Sault Ste. Marie Capt. Dearborn (1825) found in Lake Superior a tide of 1.5 ft., the ebb lasting about 2 hours and 15 minutes, and the flood about the same time. Green Bay is considered a favorable point to observe the tides and since early times (1670) daily variations have been noticed. These, as well as the oscillations in Lake Superior, are, however, due to wind; finer instruments are needed to detect the real tides. But in Lake Michigan Col. Graham found at Chicago a semi-diurnal variation of 0.125 ft. ($1\frac{1}{2}''$) for neap tides and 0.254 ft. (3″) for spring tides, with a lag of 30 minutes of the time of highwater at full and change after the meridian passage of the moon. Later observations have confirmed this, giving as an average tide for this lake 0.153 ft. The establishment for the port of Chicago is therefore $\frac{1}{4}$ ft., 0 hrs. 30 min.

The annual variation, dependent upon the seasons, is quite regular. The addition to the lakes by rainfall is greatest in summer (April to Sept.), when loss by evaporation is also greatest. Tributary

streams and the drainage basin contribute least in winter, most in spring. For a reservoir Fanning* gives as monthly gains by rain, less loss by evaporation in parts of the total annual gain:

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
+0.18	+0.19	+0.18	+0.17	+0.07	—0.08	—0.09	—0.10	—0.03	+0.12	+0.19	+0.20

The annexed diagram shows for each of the five lakes the average monthly levels as determined from gauge records, published by the

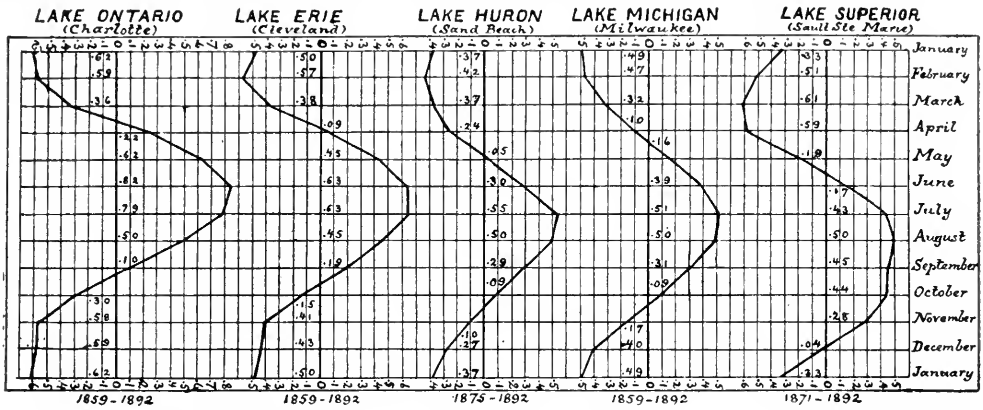

FIG. 98. AVERAGE MONTHLY LEVELS FOR PERIODS CONSIDERED (IN TENTHS OF A FOOT). PREPARED FROM ANN. REPT. CHIEF ENGINEERS U. S. A. 1892.

Chief of Engineers,** and extending for Lakes Michigan, Erie and Ontario from 1859 to 1892, for Lake Superior from 1871 to 1892 and for Lake Huron from 1875 to 1892. Highest and lowest water occur respectively in Lake Superior in August and March, in Michigan in July and January, in Huron and Erie in July and February and in Ontario in June and January. The milder climates, and therefore earlier spring-rises of the lower lakes, are plainly indicated by the earlier high waters. The difference between the levels of high-water and low-water months is for Superior 1.104 ft., for Michigan 1.001, Huron 0.962, Erie 1.203, Ontario 1.444 ft., whereas the mean annual ranges of monthly averages are respectively 1.23, 1.12, 1.11, 1.55, 1.95 ft.; and the extreme annual ranges for the periods considered 1.86, 2.24, 1.93, 2.23, 3.06 ft., and 0.66, 0.34, 0.59, 0.92, 0.67 ft.

Secular fluctuations or periodical increases and decreases of the volume of water in the lakes, extending over a series of years, were early noticed and have caused considerable speculation as to their origin and nature. In Lake Michigan they were observed by Marquette (1673), Hontan (1689), Charlevoix (1721), Whiting (1819), Schoolcraft (1820) and in Ontario by Storrow (1817). An old Indian and French tradition (Carver 1766) assigned to these variations on Lake Ontario a 14 years' period, with 7 years' rise and 7 years' fall; at the Straits of Mackinac the period was thought to be 15 years, with 7½ years' rise and fall. The New York Canal Commissioners, however, found a period of 11 years.

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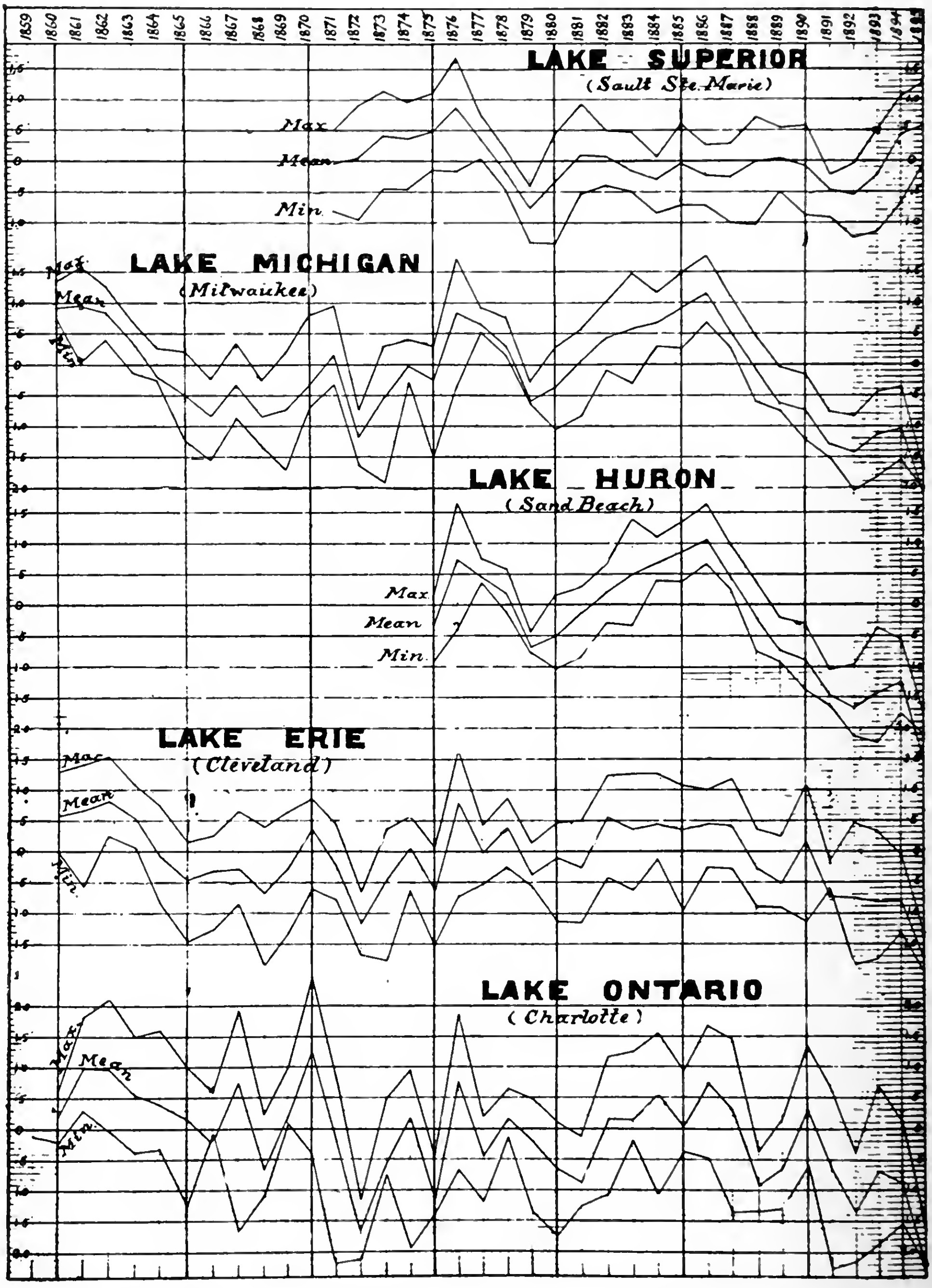
* Water Supply Engineering, New York, 1878.
** Ann. Rep. Chief of Eng. U. S. Army, 1892.



Prepared from Annual Report Chief of Engineers, U. S. A., 1892-3-4-5-6.

FIG. 99. CURVES OF SUCCESSIVE MAX. AND MIN. MONTHLY AVERAGE LEVELS, AND MEAN MONTHLY AVERAGE LEVELS FOR EACH YEAR.

It will be noticed that for some years the annual mean is lower than the geometrical minimum. Thus in 1895, at Sand Beach. min. —2.11 occurred in February, but after the max.—1 76 was reached in June. the level fell continually until in December it was —2.93 and still falling.

In the annexed diagrams, which have been prepared from the annual reports of the Chief of Engineers for 1892, 3, 4, 5, 6, broken lines connect for the different lakes the successive maxima and successive minima and annual means of the monthly average levels. The periods considered are for Lakes Michigan, Erie, Ontario 1860-1895, for Lake Superior 1871-1895 and for Lake Huron 1875-1895. Considering only natural variations of the levels, the last few years must needs be left out, inasmuch as dredging operations, undertaken since 1892 for the purpose of deepening the channels between the lakes, have exerted some influence upon the stage of the water. Irregularities in the gauge records during the last decennaries may also be accounted for by the rapid destruction of the forests and the increase of cultivated area. The levels at Sault Ste. Marie, Milwaukee, Sand Beach, Cleveland and Charlotte have been taken as means for the respective lakes, and the datum to which they are referred is the mean level for the period considered, excluding the years 1892-5, or respectively 3.215, 2.927, 2.832, 2.203 and 2.502 ft. below the planes of reference used by the Chief of Engineers, which are the supposed high water marks of 1838. That year the lakes reached their highest stage, whereas, until the last few years, the level of 1847 was considered the lowest on record and the low water therefore used as Chicago datum. The difference between these two levels is about $4\frac{3}{4}$ ft. and the total range of variations of monthly averages during the period considered, excluding the years 1892-5, is for Lake Superior 3.0 ft., Michigan 3.8 ft., Huron 3.8 ft., Erie 3.5 ft. and Ontario 4.7 ft. Records of the daily fluctuations of Detroit River go as far back as 1853, and Whittlesey has collected information about maxima and minima in Lake Erie since 1788.

In an elaborate study Hubbard* tries from all available data to find the connection between extremes of lake levels, rainfall, temperature and number of sunspots. He compares the sunspot curve for 1769-1838 with the secular variation of Lake Erie for 1788-1838, during which time high water occurred in 1788, 1800-1802, 1814-1815, 1828-1830, 1838 and low water in 1790, 1796, 1803, 1810, 1819-1820. Between 1834 and 1887 extremes occurred as follows:

Lake levels....	Max...	1838	....	47	..	58	..	70	..	82	..	Period 9-12 years.
	Min. ..	....	1841	..	53	..	65	..	75	..	..	mean 11 years.
Rainfall.......	Max...	1836	....	44	..	55	..	68	..	80	..	Period 8-14 years.
	Min...	....	1839	..	50	..	60	..	72	..	86	mean 11 years.
Temperature...	Max...	..	1839	..	49	..	60	..	70	..	82	Period 9-12 years.
	Min. ..	1834	...	43	..	55	..	66	..	75	..	mean 10.5 years.
Sunspots.......	Max...	....	1838	..	48	..	60	..	70	..	82	Period 10-12 years.
	Min. ..	1834	....	44	..	56	..	67	..	77	..	mean 10.8 years.

Thus sunspot and temperature extremes correspond directly to each other and inversely to them of rainfall and lake levels. All the curves have a steeper rise from min. to max. than the fall from max. to min.; for the sunspots the times are respectively 4 and 6-8

* Pop. Science Monthly, 32, 1888.

years, for temperature 5 and 5.4, rainfall 6.5 and 4.5, lake levels 5.4 and 5.25 years. Between 1788 and 1838 the lake rose in 5.75 and fell in 6.75 years, the mean period being 12.5 years. For the same time the sunspot period was 12.3 years and the lag of lake maxima 3.5 years and lake minima 4.5 years behind sunspot minima and maxima. Between 1834 and 1887 the lag of temperature behind sunspot extremes was insignificant; of rainfall behind temperature (inverse relation) 0-5 years, mean 1.8 years; of lake level behind rainfall 2.4 years for maxima and 3.3 years for minima, mean 2.9 years. The double lag of lake levels behind number of sunspots, with which they vary inversely, is therefore 4.3 years. If temperature depends upon number of sunspots, then rainfall and lake levels do indirectly so too. It has been claimed that a low stage of water in the streams of the Mississippi valley coincides or precedes but a year a depression of the lakes. Winds from S. and S.W. bring rain which feeds the lakes; E., N. and W. winds are relatively dry.

Periodical variations of level may also be caused by periodical lake and land breezes. Thus daily oscillations in Lake Ontario and Green Bay are produced, similar in some respects to real lunar tides. The principal changes, although of short duration perhaps, are due to winds which often raise the water on one side of the lake 2-5 ft. and in Lake Erie sometimes considerably more. An easterly gale in 1848 depressed the water at Buffalo to 15½ ft. below the level in 1849 during a westerly gale. During another westerly gale,* October 14, 1893, the elevations of the water surface were at: Toledo — 6.8, Bass Islands — 5.3, Sandusky — 2.5, Cleveland —1.2, Ashtabula —1.3, Conneaut + 3.4, Erie + 2.6 and Buffalo + 5.3 ft., a total difference of 12.1 ft. Differences in atmospheric pressure raise or lower the water level and may drive the water from one lake into another either through the connecting straits, producing such alternating currents as the early explorers noticed in the Straits of Mackinac, or through subterranean connections such as gravel beds. To each inch of difference in barometric pressure would, if there were no frictional resistances, correspond a difference of over one foot in water levels. Waves, raised by the wind, will cause momentary and local changes of the water surface. Owing to its less specific gravity and therefore less inertia, fresh water is more easily agitated than salt water. A short, choppy sea is raised quickly by the wind and subsides quickly again when the wind goes down. Waves 15 to 18 ft. high are known to have been produced by autumn gales.

Seiches are series of pulsations occurring in nearly all lakes. When, by atmospheric pressure, the water has been driven over on one side of the lake, and the pressure again is relaxed, the whole body of water will swing from side to side as in a hand basin. Regular small pulsations or rhythmic undulations, the period and amplitude of which are usually measured in minutes and inches, occur incessantly on Lake Superior, the period being about 10

* Ann. Rep Chief of Eng., U. S. Army, 1894.

minutes. In Lake Michigan a period of 15 minutes and an amplitude of a few inches was measured for east-west oscillations at Chicago. What causes these minute seiches or "embroidery" is, however, unknown; their periods are too short for oscillations from shore to shore across the basin. But the lakes are subject to other pulsations of longer periods; between Milwaukee and Grand Haven the water is known to advance and recede 11 times in 24 hours,* the period being about 2 hours 12 minutes.** Assuming the lake basin approximately parabolic, and the whole water volume oscillating like a solid pendulum around the center line of the water surface, the time of a double oscillation is, when b is the breadth and d the greatest depth:

$$T = 1.1\sqrt{\frac{b^2}{8d} + \frac{4}{7}d} \quad \text{or approximately} \quad 0.39\frac{b}{\sqrt{d}}$$

Substitution of the values at the south end of Lake Michigan, i. e. b=60 miles=316,800 ft., d=240 ft. gives T=7953 seconds=2 hours 12½ min. or the same as the period actually observed.

Such uninodal, stationary vibrations or waves of libration, by which the water is caused to rise at one side or end of the lake at the same time as it falls at the other and vice versa, were studied at the end of last and the beginning of this century by Jallabert, Bertrand, Saussure and Vaucher. In later years Dr. Forel*** has experimented with artificial basins and on a great number of Swiss lakes. They observed seiches on Lakes Geneva, Neuchâtel, Zürich, Constance, Lugano, etc., or on nearly all the Swiss and North Italian lakes. In the Scottish lochs such regular oscillations may be looked for, as extraordinary seiches are recorded, such as the great disturbances in Loch Tay in 1784 and 1794. Only in lakes of regular form are the seiches regular. Their period or rhythm, which is the time between two successive wave crests or hollows, shows a great regularity, but their amplitude, even at the same place, is very variable, being usually small when the atmosphere is at rest, but greater when the atmospheric pressure varies, and increasing when, or even before, the barometer is falling at the approach of a storm. Seiches are therefore most noticeable in spring and autumn. They are greater at the extremities than at the middle of a lake and vary, as tides, with the configuration of the shore. They are also less complicated at the ends of the lake than at its sides, where the longitudinal vibrations are combined with transversal. Forel found the period of the longitudinal seiche to vary directly as the length of the lake and inversely as the

* Ann. Rep. Chief of Eng. U. S. Army, 1872.

** Sailing directions for Lake Huron, published by Hydrographic Office, 1894.

*** Nature 18, 1878, and "Biblioteque Universelle et Revue Suisse."

square root of the mean depth. Self-recording gauges, called "limnimetres," were established in Lake Geneva at Morges, where the period was 630 ± 18 sec. (10 min. 30 sec.); Veytaux, where it was 1783 sec. (29 min. 43 sec.), and Geneva, where it was 4380 sec. (1 hour 13 min.). In Lake Neuchâtel the period is at St. Aubin 264 sec. (4 min. 24 sec.) and at Yverdon 2840 sec. (47 min. 20 sec.).* A harmonic analysis of the Geneva curves discloses, however, several systems of undulations, one of which has a period of 1 hour 12 min. and another 35 min.

Besides these more or less regular seiches, due, undoubtedly, to local variations of atmospheric pressure, exceptionally great and sudden seiches occur which the mariner refers to as mysterious lake tides or "swashes." They are often rather local in character and not accompanied by any wind; may, however, extend over larger areas and be preceded or followed by winds. It seems that they only take place at the time of a sudden and decided rise or fall of the barometer. With a loud, hissing sound and strange noises, heard out on the lake, but not with the roar of the ocean surf, a 4-8 ft. high wave suddenly rises from the often perfectly calm water surface, perhaps only a couple of miles from shore, and sweeps shoreward. A white squall may be seen on the lake, perhaps a little waterspout, bubbles may rise to the surface of the water and fish appear as if stunned (Oswego 1872). In ten minutes the lake is again smooth and calm; but generally a series of three or four, usually decreasing, swashes follow the first one within an hour or two.

Of such unusual seiches one, about 5 ft. high, was observed in Lake Geneva in August, 1763, and another, 7 ft. high, in October, 1841. In Lake Erie one is mentioned as early as October 1764, another in December, 1856, is said to have been nearly 8 ft. high. The one observed by Major Wilson in Lake Ontario on June 13, 1872, had a period of 20-30 min. In Lake Superior a seiche of unusual height occurred in August, 1845, and in 1854 St. Mary's River was left nearly dry for about an hour. One in April, 1858, in Lake Michigan, which was followed by two other ones, is said to have had a period of only 10 min. Another, which occurred in 1868, had an amplitude of 3 ft., a period of 15-20 min., and continued to ebb and flow during a whole day. It was preceded by a variety of signs,** suct as mirage, low barometer and a sudden rise of the temperature; the wind, which was off shore during most of the day, suddenly veered to the opposite quarter, changing to a violent gale accompanied by vivid electrical displays. The largest seiche known in Lake Michigan occurred on April 7, 1893, being noticed simultaneously at Chicago and St. Joseph, Mich., and rising to a height of 4-6 ft. According to the statement of H. C. Frankenfield high winds had been blowing at Chicago for 11 hours from

* Encycl. Brit. article "Lakes."
** Thompson's Coast Pilot for the Upper Lakes, Detroit, 1869.

S.E. (30-40 miles per hour) and shifted to N. N.E. immediately (0-15 min.) before the wave occurred. An automatic gauge record of the variations in the lake level at Chicago has appeared in a report by Major Marshall.* It extends over 24 hours on August 16, 1886, when an area of low pressure passed over the lake. The curve shows the regular 15-20 min. oscillation, the amplitude of which is a few inches, but, combined with it, another larger oscillation with a period of about 40 min., 26 waves occurring in 18 hours. The third wave, which is the greatest, has an amplitude of 2 ft. 10 inches, the water falling this distance in 15 minutes.

What causes these swashes is a mystery. The most plausible hypothesis, which seems confirmed by the observations at Oswego in 1872, i. e. that they are produced by earthquake shocks and submarine eruptions, received a serious setback when an earthquake in Switzerland in 1877 left no trace on the "limnimetre." Forel therefore abandoned this theory and sought the cause in violent downward gusts of wind acting upon the lake. The truth is probably that sometimes one and sometimes another agency causes the phenomenon; for even though some earthquakes do not produce seiches, others may.

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* Survey of a waterway from Lake Michigan to the Illinois River, 1890.

Western Society of Engineers,

ROOMS, 1737 MONADNOCK BLOCK,

CHICAGO, ILLS.

OFFICERS FOR 1896.

PRESIDENT,
John F. Wallace.

FIRST VICE-PRESIDENT,
Thos. T. Johnston.

SECOND VICE-PRESIDENT,
Alfred Noble.

TRUSTEES,

Robert W. Hunt,
G. A. M. Liljencrantz,
Horace E. Horton.

TREASURER,
Emil Gerber.

SECRETARY,
Henry Goldmark.

STANDING COMMITTEES,

Membership: Alfred Noble, Horace E. Horton, E. Gerber.
Finance: E. Gerber, L. P. Morehouse, Hiero B. Herr.
Publication: J. J. Reynolds, Thos. T. Johnston, Chas. E. Billin.
Library: G. A. M. Liljencrantz, John Lundie, Frank P. Kellogg.

COMMITTEE ON PROFESSIONAL PAPERS,

John Lundie,
A. V. Powell,
W. L. Stebbings,
A. M. Feldman,
J. W. Cloud,
E. L. Cooley,
G. M. Basford,
G. L. Clausen,
W. D. Hotchkiss.

ENTERTAINMENT COMMITTEE,

Geo. P. Nichols,
C. E. Schauffler,
T. L. Condron.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—MAY 6, 1896.

A regular meeting (the 344th) of the Society was held in the Society's rooms, 1736–9 Monadnock Block. May 6, 1896, at 8 P. M., 1st Vice-President Thos. T. Johnston in the chair. There were 37 members and guests present. The minutes of the previous meeting were read and approved.

The Chairman of the Entertainment Committee stated that arrangements were being made for an excursion to South Chicago to visit the works of the Illinois Steel Company, to take place at a future date, and that notice would be sent to all members in due time.

The Secretary announced the appointment, by President Wallace, of Messrs. Edgar Williams and John Ericson as a committee to act with the Illinois Society in the matter of Sanitary Legislation.

The Secretary was instructed to express the thanks of the Society to the proper official who extended an invitation to this Society to attend the Mining and Geological Millenial-Congress, to be held at Budapest, Hungary, September 25th and 26th, 1896.

MINING AND GEOLOGICAL MILLENNIAL-CONGRESS.

OFFICE OF THE EXECUTIVE COMMITTEE.

(6. Bulyovszky-utcza).
BUDAPEST, February 20, 1896.

To the Members of the Western Society of Engineers:

The Metropolitan City and residence of the King of Hungary is preparing to solemnize this their millennium by a series of great festivities.

A thousand years have passed since our country has sprung its existence and has assured its liberty in the very heart of Europe.

After many hard struggles which often threatened our total annihilation, we have firmly held our ground and are now going to extend, in an intellectual and ethical point of view, the construction of our public life.

We mountaineers and geologists will do our share in the demonstration by convoking our colleagues from abroad to debate with them on subjects of mutual and scientific interest.

We have, therefore, decided to hold the 25th and 26th of September, 1896, a Mining and Geological Congress in connection with the Millennial National Exhibition, and we hope to welcome all those of our friends and colleagues who may choose to take part therein.

We presume that our National Exhibition alone will afford some interest to those not fully acquainted with the situation of our country, but we shall feel happy if our invitation will also result in inducing the participation in discussions.

It is proposed that on the days destined for the meetings of this Congress the rich Exhibition of Industry and Agriculture, as well as its most interesting historical features, shall be visited under professional guidance.

According to the number of foreign and home members, discussions will be opened in special sections, for which reason we have decided to constitute the following sections:

(*a*) Geology.
(*b*) Coal-Mining.
(*c*) Metal-Mining.
(*d*) Preparations of Metal ores in a wet way.
(*e*) Proceedings of extracting metal.
(*f*) Iron-ore Mining and Metallurgy.
(*g*) Rock-salt Mining
(*h*) Mintage and
(*i*) Mining legislaturu.

Lectures as well as the discussions to be held can be made not only in Hungarian, but also in German, French and English.

Notices of lectures to be given at latest until the 1st of April, a. c., and rough copies of the same to be sent to the undersigned Committee the latest until the 1st of July, a. c., in order to give time to have them translated into other languages and to have them put into print.

After the closing of the Congress, excursions of two to three days' duration, will be made into some of our most important coal mines, iron works and interesting gold districts.

In the name of the Executive Committee, I have the honor of inviting you to partake in our Congress, and hope you will be largely represented by members who, by lectures and arguments on questions of national-economical importance, will enliven our discussions and add to the success of this Congress.

Finally, I beg to observe that notice of participation can be registered at my office (Budapest VII., Bulyovszky-utcza 6), until the 1st of July, a. c., and that our Committee will also undertake to provide suitable lodgings for the members if required to do so.

We are, with great respect, truly yours,

A. v. KERPELY,

President, Executive Committee.

Report for the Board of Directors was made by the Secretary, as follows: At meeting held April 17th, applications for active membership were received from Dabney H. Maury, Jr., James S Stephens and Edward J. Murphy.

Charles F Foster was declared elected as an active member.

At a meeting held April 21st, applications for active membership were received from Frank Bankson Rae and William J. Buckley. The resignation of J. G. Pearson was accepted, to date December 31, 1895.

At meeting held May 5th, applications for active membership were received from Edward M. Herr and Gustav Vogelsberger.

The following were declared elected to active membership: Julian Switzer Hull and Frederick Henry Dose.

Owing to the small number visiting the Society rooms in the evening it was decided to close them at 5:30 p. m. hereafter.

Then followed a very interesting paper on the subject of "FOUNDATIONS" by Mr. George E. Thomas, which evoked considerable discussion of a profitable character. The paper and discussion in full will be printed in August issue of the *Journal.*

On motion the meeting adjourned.

HENRY GOLDMARK, Secretary.

REGULAR MEETING, JUNE 3d, 1896.

A regular meeting (the 345th) of the Society was held in the Society's rooms at 8 o'clock P. M., June 3, 1896.

In the absence of the President and both Vice-Presidents, Mr. Emil Gerber, Treasurer, was elected to the chair. Thirty-four members and guests present.

The reading of the minutes of the previous meeting was dispensed with. The Secretary made report for the Board of Direction, as follows:

At Board of Direction meeting, May 18, 1896, the resignation of Mr. C. H. Vehmeyer was received and accepted. Mr. Henry Goldmark, expecting to be absent for an indefinite period, resigned as Secretary, and was excused from duty and responsibility till August 1, '96, and Mr. Nelson L. Litten appointed to act in his stead.

At the meeting June 2, 1896, the following named gentlemen were declared elected to active membership in the Society: Messrs. Frank Bankson Rae, Edward J. Murphy, and Dabney H. Maury, Jr.

Application for active membership of Chas. S. Kaufman was received, read, placed on file, and referred to the Membership Committee.

Mr. Liljencranz, Chairman of the Library Committee, made verbal report that a catalogue of the library has been practically completed in the shape of a card index, and there is now a considerable fund of information easy of access open to members.

The Secretary then read the following letter:

HEADQUARTERS FIRST BRIGADE.

ILLINOIS NATIONAL GUARD.

Chicago, May 16, 1896.

Board of Directors—Western Society of Engineers:

Gentlemen:—Having received instructions from the Adjutant General's office to enlist 30 engineer soldiers, as a nucleus for the "Engineer Corps," I. N. G., until action can be taken by the next Legislature to fill it out to 100 men, I take the liberty of addressing the Society in order that these men, first enlisted, may be of a high professional character.

An equipment has been purchased with suitable wagon for its transport, together with mule harness, pack saddles, etc. The field outfit consists of mathematical instruments and ample tools for construction work on railroads, trestles, span bridges and field fortifications. Athletic young men of technical training are desired. Instructions in military engineering will be given with blackboard and by modeling in the sand box with miniature gabions, fascines, etc.

In the field, actual construction work will be done by working parties of infantry under the supervision of engineer soldiers. The First Brigade, with 2,500 men, will go to Springfield in July for one week, and a series of battle exercises and maneuvers will take place, on a larger scale than ever before attempted here and over a larger area.

Intrenchments and bridges will be constructed and much topographical work will be done. The equipment of ordnance and quartermaster stores will be of the most modern pattern.

Discipline in camp and at drill will be rigid, but theoretical instruction will be imparted in the most informal manner, and officers of the regular army will be invited to deliver lectures on military topics.

All men must go to camp. Until camp, two drill nights a week; after camp, one. No hardships are imposed, and there is no interference with private occupations. If a man leaves the city an honorable discharge is forwarded to him.

The advantages of enlistment are briefly; the voluntary performance of a civic duty; no expense; acquired knowledge of military engineering; a military bearing and correction of defects in personal gait, due to too much office work and lack of athletic exercise; intimate association and comradeship in the highest branch of the staff corps with men of kindred tastes and pursuits in civil life; ultimate promotion in the staff corps or the line; development of executive ability by its exercise in handling men, always with the soldierly idea that the only way and the simplest way to do a thing is to do it right. Objects to be obtained by the Corps as a whole are, highest perfection in drill, in marksmanship and in its technical field duties.

If your honorable board will kindly bring this matter before the young men of the society, I am sure the courtesy will be appreciated by them as, I assure you, it will be by the Adjutant General's office.

Very respectfully, your obedient servant,

CAPTAIN JOSEPH I. KELLY,

Engineer officer, First Brigade, I. N. G.

An interesting and valuable paper on the Geology and Hydrology of the Lakes, by Mr. P. Vedell, was read. Remarks upon the matter presented were made by Mr. Morison and others. The paper is printed in full in this issue of the *Journal.*

On motion the meeting adjourned.

NELSON L. LITTEN, Acting Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid materially in completing valuable volumes for our files.

Since the issue of No. 2 of the Journal we have received the following as gifts from the donors named :

Mr. V. G. Bogue—73 numbers Engineering News, of Vols. 29, 30, 31 and 32.
Mr. O. Chanute—4 volumes Engineering News.
Mr. C. E. Billin—38 pamphlets, papers and periodicals.
Mr. Jose de Cuto—86 numbers Engineering News, 1887 to 1895.
Mr. H. Elmer—84 numbers Engineering News, 42 numbers Engineering Record.
Mr. Hiero B. Herr—Vols. 29, 30, 31 and 32 Engineering Record, 21 copies of other periodicals.
Mr. Love—2 volumes Electrical World, 1894-5; "Power" for 1893, complete; 60 numbers of Electricity; 103 copies of other periodicals.
Mr. C. J. Morse—Engineering News for 1895; Engineering Record for 1895; Railroad Review for 1895; 40 copies of the foregoing for 1896.
Mr. Peabody—18 copies Engineering News, 1894.
Mr. Richardson—75 copies of various periodicals.
Mr. Emil Gerber—60 periodicals.
Mr. J. J. Reynolds—100 periodicals and pamphlets.

Thanks are also due to other friends.

Our reading room is open till 5:30 p. m., on week days, except Saturday until noon, during summer months.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

VOL. I. AUGUST, 1896. NO. 4.

IX.

DEEP AND DIFFICULT BRIDGE AND BUILDING FOUNDATIONS.

BY GEO. E. THOMAS, M. W. S. E.

Read May 6, 1896.

Mr. President and Gentlemen:

It is not my purpose this evening to tell you what is to be done, or to give figures on the carrying capacity of piles, or any other form of foundation, but simply to start the opening wedge that will bring about a discussion on foundation work in general, also to give to the younger members of our society some of the plans that have been adopted and used.

You have other members in this society who can, and I have no doubt will, bring this matter more forcibly to your minds than I can. Any information or assistance in my power will be freely given to those seeking it to the best of my ability.

To all engineers and architects this is a very important problem and of vital importance to the public.

Very few people understand the difficulties encountered and obstacles to be overcome in putting down the pneumatic caissons for such bridges as those which span the Ohio River at Cairo and Cincinnati, the Mississippi at St. Louis, the Susquehanna at Havre de Grace, and the Missouri at numerous points.

I will not attempt to describe the vexatious problem and the many difficulties encountered in securing the right of way, etc. This is a matter I have never had to enter into. Mine has been in the practical rather than the diplomatic.

You are all doubtless familiar with the form of our iron and wooden caissons, and understand that as soon as we reach the bed rock or the point of destination, whether it be of rock, clay or any other substance, the caisson has outlived its usefulness, except the part called the roof, on which a monolith of concrete

is used, which is the case in nearly every instance. This roof comes immediately between the concrete on which the masonry rests and the concrete used in filling the working chamber, consequently the less timber there is used in the roof, the less the compaction will be. Mr. George S. Morison in his system of caissons has reduced this to a minimum, as he has so arranged his plan that he forms an arch of concrete on a thin roof, thus doing away with the necessity of many courses of timber to sustain the weight of masonry, etc.

The sides of caissons must have sufficient strength to resist the inward pressure. We are to assume the whole load, let that be what it may, due to the full depth of material which we have to pass through, and the accumulated weight put on the roof, as there are times when we let off all our air, thus bringing all the strain on to the side, less the resistance of the water which will return to working chamber when air is let out; indeed, I have experienced much difficulty after taking every precaution. In passing through gravel especially, I would cite the caissons used for the C. & O. bridge, crossing the Ohio River from Cincinnati to Covington. We used in the construction of those caissons, which were eighty feet long by forty-five feet wide, eight feet working chamber, white oak timber, making the sides of 12′ by 12′, three thicknesses, also four courses of 3″ oak plank, put on on an angle of 45 degrees. And again a vertical facing of 3″ plank outside of everything, and lining the inside with white pine plank. This pine lining enables us to do better calking work. We used a truss running longitudinally through the caisson. This was composed of two chords, top and bottom, 24″ wide, and posts 12″x12″ every 6′, all tied up to the roof with heavy rods. We also put in cross braces, 18″ square oak. Every 10 feet those butted on to a bolster, which was fastened vertically on side of caisson, and before we had settled caisson on bed rock, those braces had crushed into the bolsters over three inches, but by persistent effort and untiring watchfulness we reached the looked for bed rock and on those piers stands one of the longest truss spans in America, and, I may say, one of the heaviest structures.

In sinking those piers we had numerous obstructions to encounter. Among other things part of a wrecked steamer; also three rafts of oak saw logs which had sunk over the piers' site; all of which had to be removed by manual labor, taken out piece by piece, and all this under water. We also found a natural concretion of gravel and sand, very hard; I would say, about equivalent to local cement concrete. We often find queer things when we reach bed rock, such as fossils, old implements, bones of animals, etc. I have found whiskey bottles, but those were of recent date.

The piers which I have put down in other rivers differ somewhat from those in Ohio River; in fact, every river has its own characteristics. Those put down in Missouri River for Platsmouth

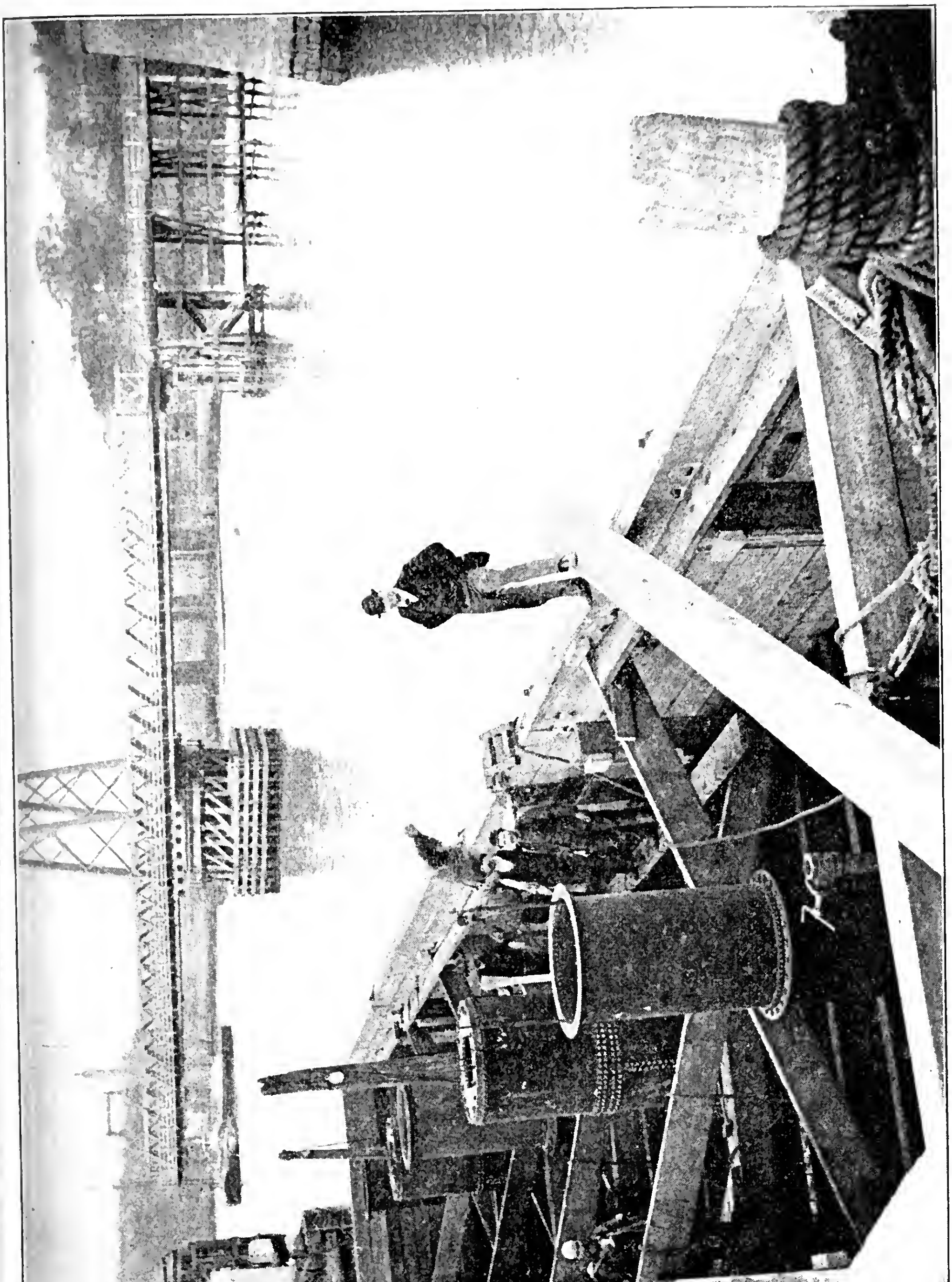


FIG. 100. WEST ABUTMENT CAISSON, CENTRAL BRIDGE, 155TH STREET, NEW YORK CITY. ON TOP, LOOKING DOWN AFTER IT WAS IN POSITION.

Bridge for Mr. George S. Morison, by Sooy Smith & Son, and under my supervision, were sunk very rapidly. I may say the time taken to put them down has never been beaten, and notwithstanding that those piers were put down in 1880, I have no recollection of a better constructed timber caisson.

While sinking those piers I was approached one day by two gentlemen, one introducing the other as a newspaper man to me. He said his friend was somewhat bashful, but would like to ask me a few questions, and being rather that way inclined myself, we soon understood each other. After asking several questions, he finally came to the one to him most important, and confidentially asked me "where we got the air from we used in our compressors?"

I immediately informed him that this was one of the secrets of the profession, but that, as I did not like to treat a newspaper man in anything but the true spirit, I said we were using Omaha air to-day, but that I had sent to Chicago for some of its air, as there was more ozone in it. He was very thankful to me for my explanation, etc., and went away content. It is needless to say he did not pay me any more scientific visits.

The piers put down at Havre de Grace were of a different construction from those used at either of the before mentioned places. In those we used horizontal timbers on the inside and vertical timber extending up fifteen feet on the outside; all thoroughly bolted with screw and drift bolts. We also used a system of truss and braces and the interior lining for caulking was about the same character as that used in my other work. The roofs were of several courses of 12″x12″ timber thoroughly bolted to the side courses of caisson and to each other. The material through which those on the east side of Garret Island were sunk was mostly silt, with some clay and loam we also found leaves of trees and some boughs immediately on the bed rock, showing very conclusively the necessity of going to the rock with our heavy structure, as what has been, may occur again. The pier known as No. 9 we put down over 90 feet below low water. We experienced great difficulty in locating and keeping this one in position, there being 40 feet of water to start with, and the surface of silt was very soft, added to this the flow of tide, all adding to our difficulties and anxiety. However, we made a success of this work; and today on those piers stands one of the great bridges of America.

I have not time to give you a more full description of those works, as I find I must hurry along.

I will now try to describe a different form of caisson, put down by Sooy Smith & Co., of which I had charge, namely, those for the bridge over the Harlem River in New York City. We put down for this work three forms of caisson, viz., rectangular and annular of steel and rectangular of timber; the one for the west abutment (Fig. 100) being rectangular, one hundred feet long, nineteen feet wide and fifteen deep, with a working chamber of eight feet with timber cofferdam on top which was removed when the pier

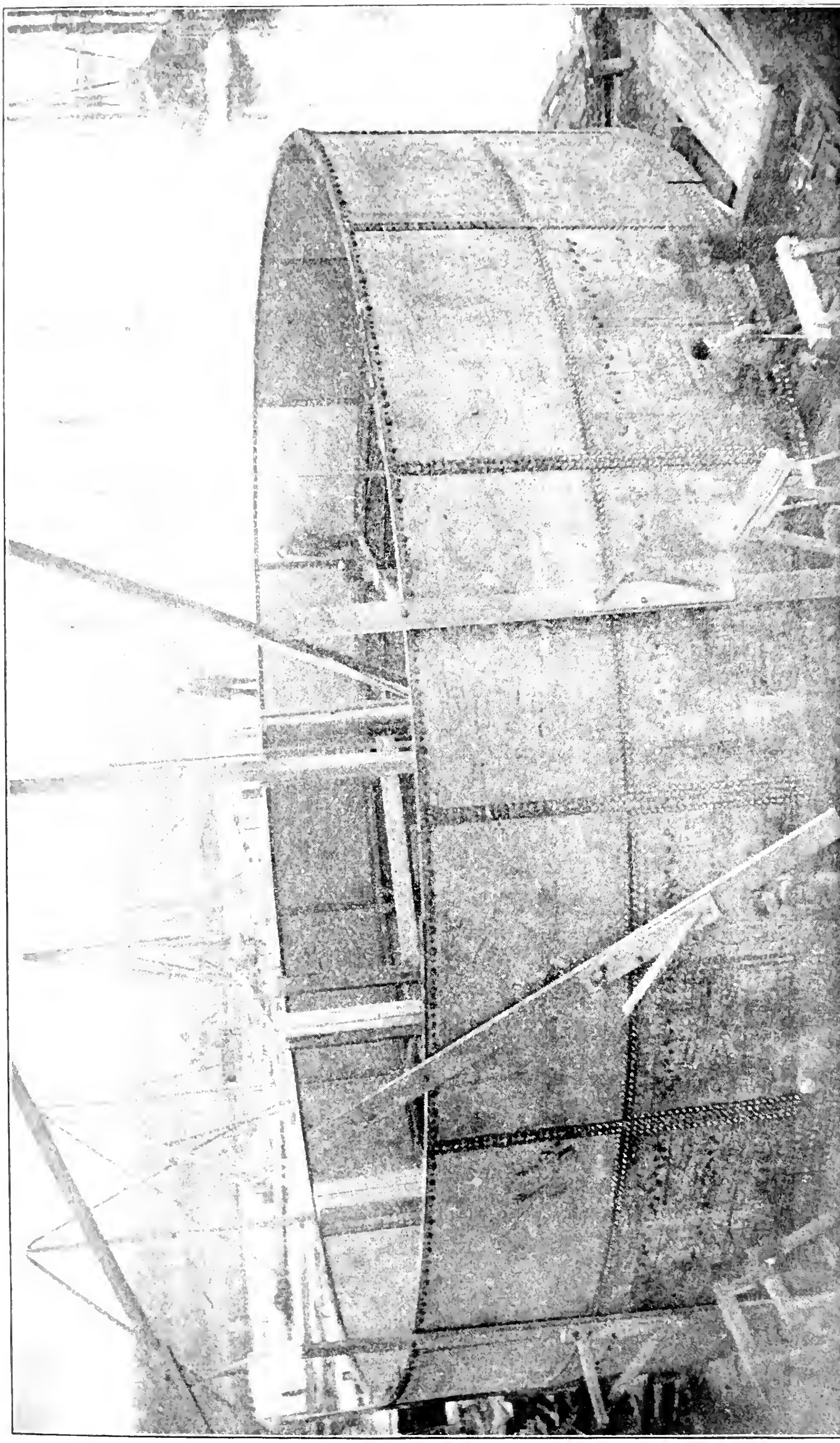


Fig. 101. Shell of Annular Caisson for Pivot Pier, 155th Street Bridge, New York City.

was brought to water surface. This caisson was built of steel by the Passaic Rolling Mill Company. It was constructed on the shore immediately west of its final resting place, and turned over to me, resting on the blocking. I lowered it down into the water between tides. This was a difficult matter, as the time was so short between the ebb and flow and the poor foundation on which it had been built, this being composed of ashes and refuse from the dump carts of Harlem. However, this we accomplished without accident of any sort, and when we got ready we floated this into position, using compressed air on the inside, closing all doors and valves in the roof, displacing the water from air chamber to a proper depth, and in this way lifted the caisson and carried it out to its exact location, and settled it down to the river bottom, by allowing the air from within air chamber to escape through a system of openings, provided for this purpose. The weight of the caisson when put in place was about one hundred and twenty-five tons.

This was a very difficult caisson to handle from the start, its being so narrow and top heavy, also having fluctuations of tide water to contend with; and we landed the west side on rock before we had a very strong hold on the bottom. We settled this caisson through sixteen feet of rock on the west before we reached it on the east side. We finally made perfect success of this pier. I would say that in my judgment steel or iron is more reliable for caisson construction than timber, if for no other reason—the difference in the thickness of material between the concrete in chamber and base of pier, brings the opportunity for settlement down to one-half inch plate of steel or iron.

The caisson for pivot pier was annular (Fig. 101), having an interior wall, with air space of six feet between inner and outer walls. After putting this caisson in position, I was removed to 68 Broadway, and took charge of the pneumatic caisson put down to carry the Manhattan Life Insurance Building at the above number. We used under this building fifteen steel caissons of various forms. Those were put down on an average of fifty feet below the grade of Broadway. We held up the Consolidated Exchange Building on one side, and immediately next north of us was a very old six-story building, and adjoining this was the heavy Title and Trust Building. So effective was the plan adopted to do this work that we did not even crack plaster in those surrounding buildings.

The Manhattan Building was planned by Kimball & Thompson, architects, of New York; and to those gentlemen is due the credit of adopting the pneumatic plan for sub-structure of buildings.

As before stated, the caissons were built of steel, and immediately on the roof plate we started the brick pier, carrying this up to the required height, without any shield. We used in the construction of those piers eight hundred tons of steel, and to bring the tops of piers to a level of a cellar floor, over two million brick, set in Portland cement. We also removed five thousand yards of

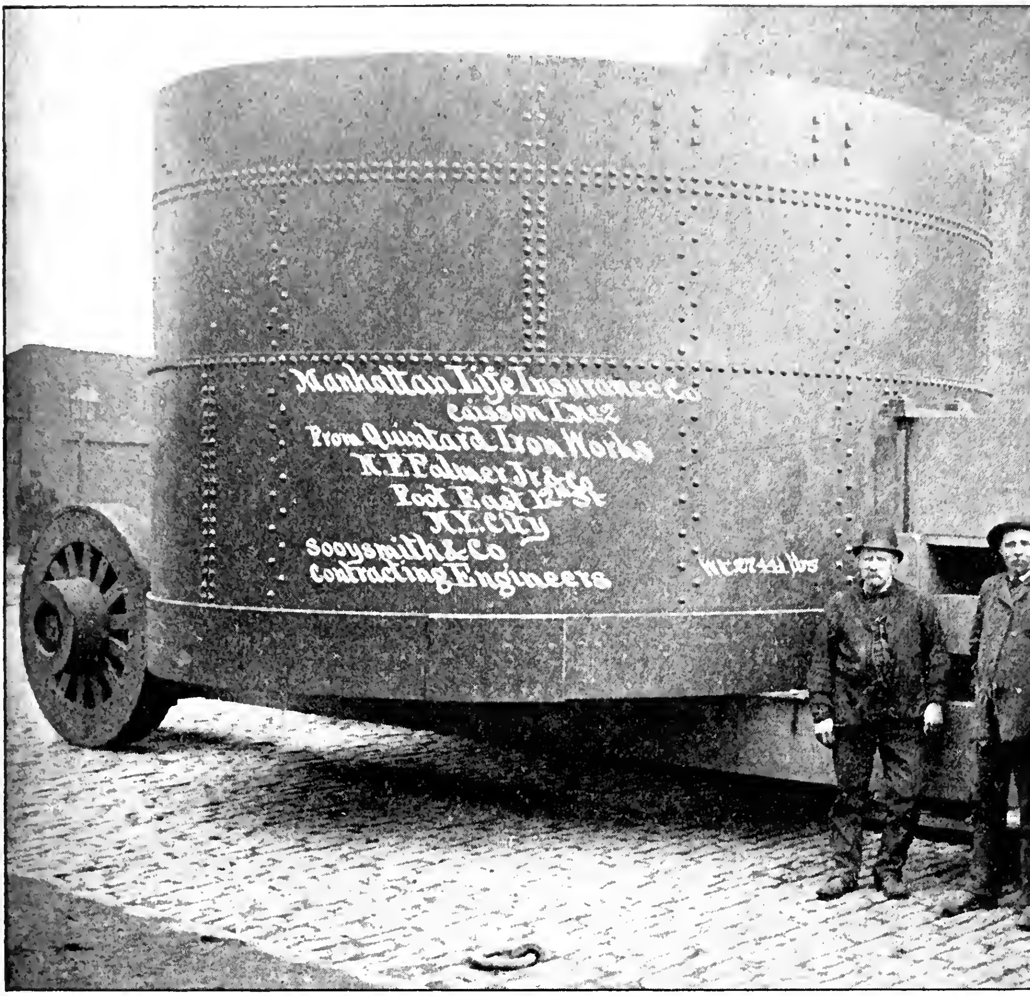


FIG. 102. ONE OF THE SMALL CAISSONS, MANHATTAN LIFE BUILDING, 66 BROADWAY, NEW YORK CITY.

excavation through that busy section of New York, and completed this work in ninety days, and this without accident.

One thing I am very proud of—and thankful for—that I have never had a man lose his life under my supervision during my pneumatic work. Most people are afraid of compressed air. I have had a number of men, who, through physical disability, have been overcome, but in every case I have pulled them through. The men who suffer most are those who use up their vitality during the hours of rest, and come to work in many instances after being on a debauch, etc.

I have not the time to tell you of more of those foundations at present.

Will just mention that we have as yet said nothing about the freezing plan for our substructural work. This enables us to go beyond the possibilities of man's endurance under compressed air.

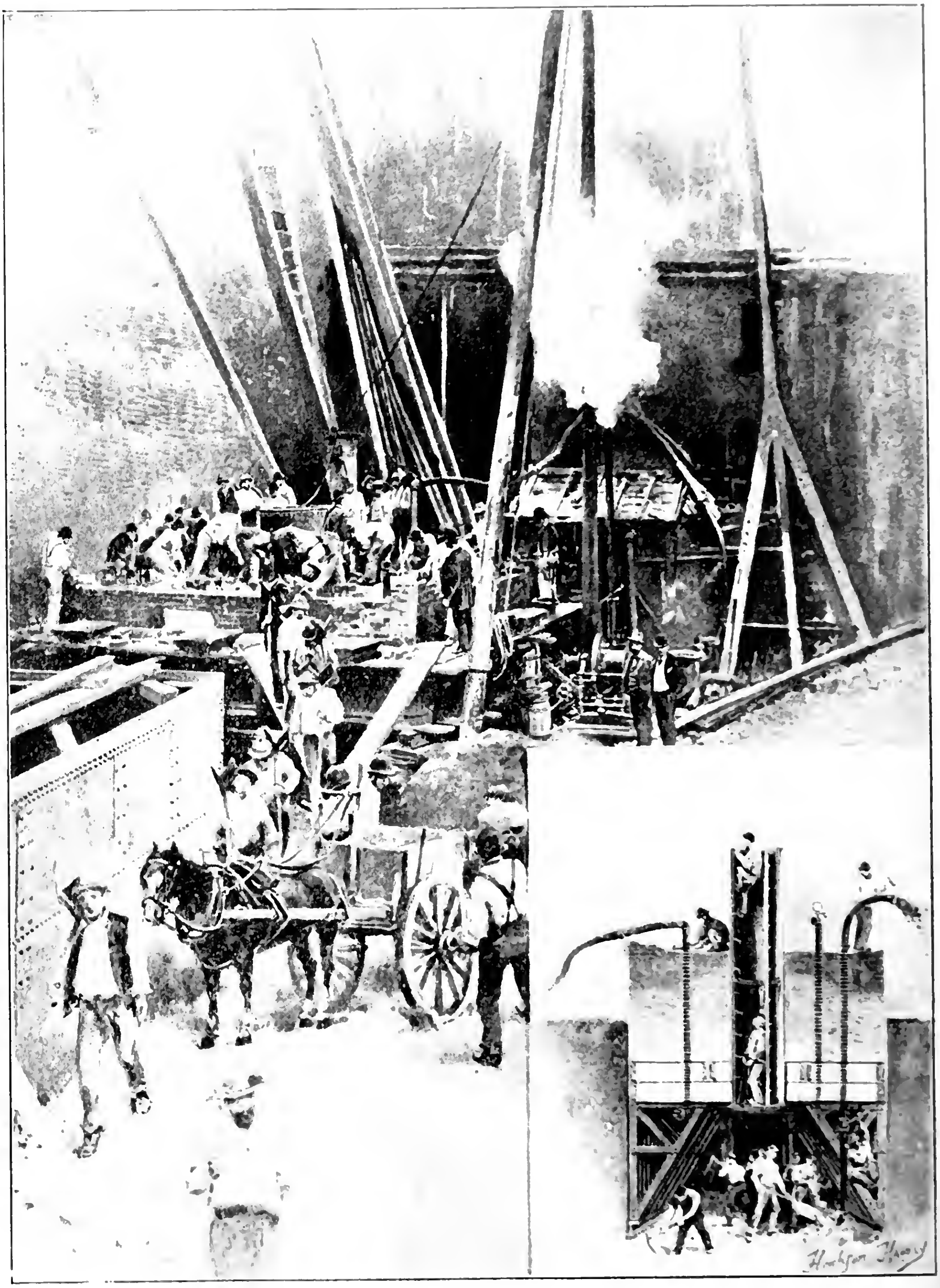


FIG. 103. WORK ON FOUNDATION IN PROGRESS, MANHATTAN LIFE BUILDING, NEW YORK CITY.

By this process, we can defy the flowing quicksand, water-bearing materials, or even water, and hold it absolutely rigid until such time as we have completed our work. There have been several shafts sunk by the Poetsch system in Europe, and one in this country.

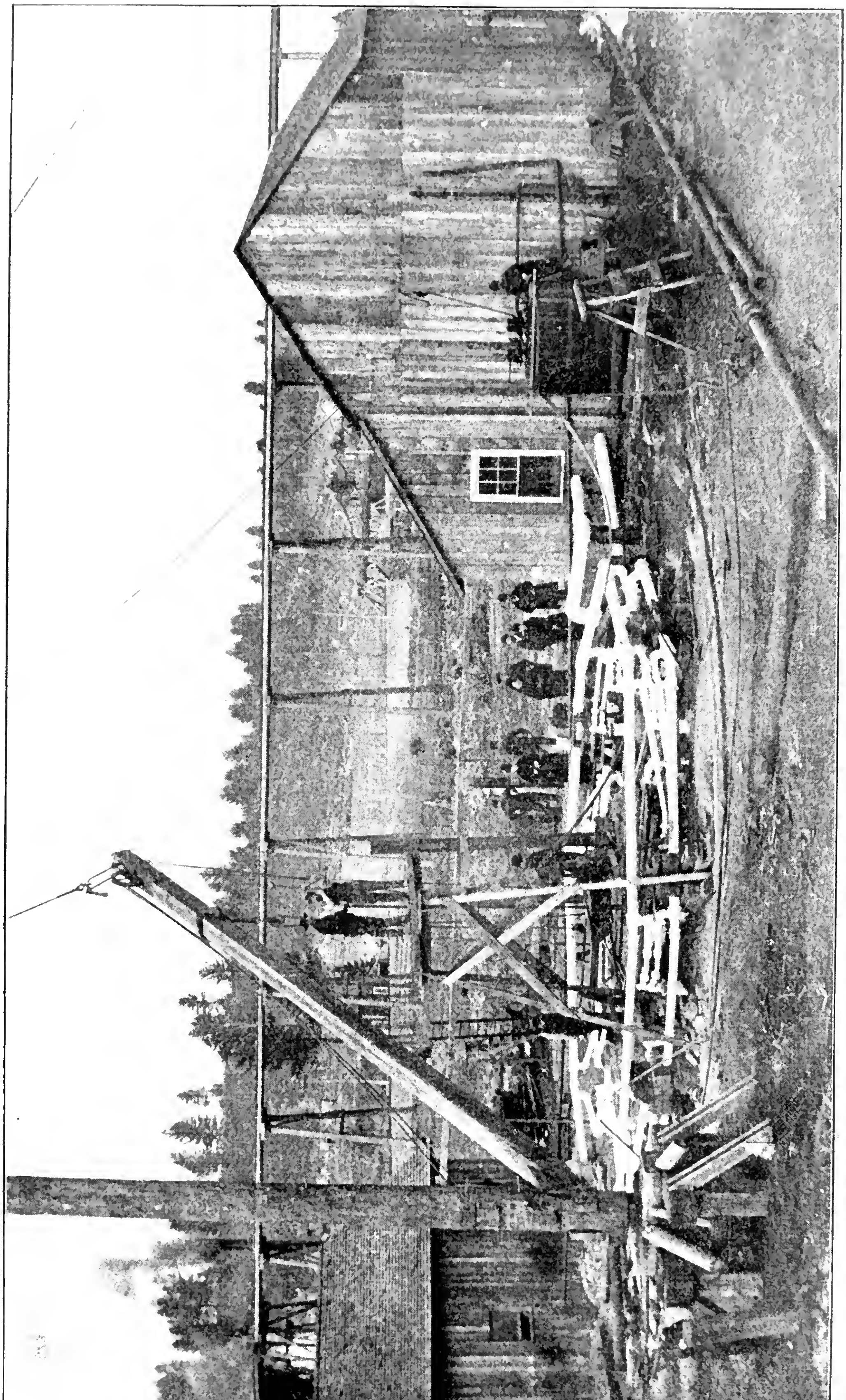


Fig. 103. Freezing Plant, House and Derrick. Taken 48 Hours After Starting Ice Machine.

The plan adopted to put down a shaft at the Chapin Mines, Iron Mountain, Michigan, was that of boring down through the water-bearing quicksand to the solid rock, one hundred and four feet, with a ten-inch pipe.

Those pipes were put down through this sand and boulders by using a powerful jet on the inside of pipe. The pipe was held by a heavy frame in a vertical position, and on this frame was fastened a short section of the same size pipe with a large cog-wheel attached; in this was worked two pinions attached to the engine shaft, employed to give the rotary motion needed. Boring down those pipes was quite a difficult work, owing to the large number of boulders bedded in the sand. While sinking the shaft we found and removed, among others, one which weighed over seventeen tons. We also had on the point of pipe a toothing of steel.

After those pipes had been jetted and bored down to solid rock, we then inserted in the ten-inch pipe one of eight-inch diameter, with a cap on the bottom end, and then withdrew the ten-inch pipe, care being taken to make every joint in eight-inch pipe absolutely tight, as any leakage of the circulated non-freezing fluid into the sand on the outside would prevent the sand thus contaminated from freezing. After we had put in all the pipe needed to form the circle required, we put down the inside of each of the eight-inch pipes, a smaller one for circulating purposes. This pipe was one and one-half inches in diameter, and was open at the bottom and connected at the top to a header, and this, with our circulating pump, was in turn connected with our fluid tank, containing our heat absorbent, which was composed of chloride calcium in solution. This congeals 35C.,—31—Fahr.

This we reduce to a very low temperature by the use of an ice machine. We used for this work the Linde machine, which we charged with anhydrous ammonia; compressing this to a high pressure, then passing the ammonia through a coil of pipe submerged in a tank, into which we pumped cold water, delivering the water at the bottom of the tank and allowing this to overflow at the top, carrying with it the heat produced by compressed ammonia in the submerged coil, the length of pipe in coil being at eight thousand feet. After receiving this cold bath the ammonia passes to the expansion valve; when expanded it became intensely cold, somewhat changing its form from that of anhydrous to semi-gaseous. This passes then through another coil of pipe about eight thousand feet in length, which is submerged in an out-tank containing our cold-producing fluid. And after doing its work here it is conducted back to the ice machine to be compressed over; and in this way kept circulating through the coils of cold-producing pipes. The cold fluid is then taken up by the circulating pump and forced through the whole system of pipe in the ground, absorbing the latent heat. This fluid being delivered at the bottom of the stand pipe (Fig. 104) raises that on the outside of the $1\frac{1}{2}''$ pipe; it is then conducted back and delivered again over the top of the tank for re-cooling. Our circulating pump be-

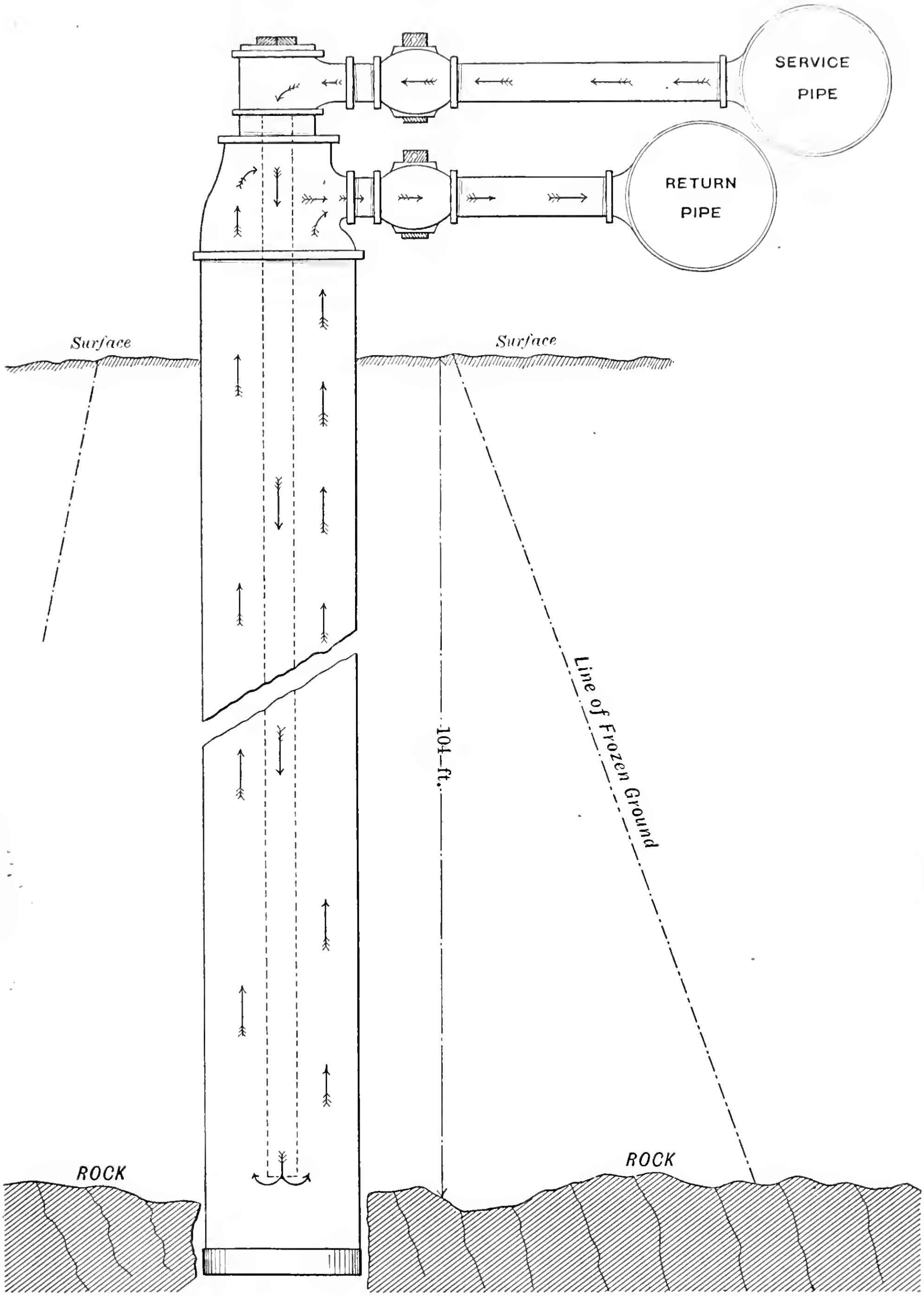


FIG. 104. STAND PIPE THROUGH WHICH THE FREEZING FLUID CIRCULATED.

ing attached to the bottom of the tank, we at all times get the coldest fluid. The difference of temperature of the fluid returning and going out is two degrees less. We had about fifteen thousand gallons of this fluid in pipes and tank, which we circulated through the system of pipes every thirty-three minutes. We regulated this flow into the stand pipe by a system of valves. In his way I was enabled to get the same flow into each stand pipe, consequently the same temperature in each. The frozen ground took the form of a cone. As soon as I found that the frozen ground between each pipe had become united, we started our excavation, going down forty feet before I put any timber in. From tests made by myself down in the shaft during the progress of the work, I found the quick-sand when frozen to be about equal to sand-stone in strength, and required blasting to take out, using heavy charges of dynamite.

We found that, as the work went on, we could, and did, stop the freezing machine for several hours at a time. This did not seem to injure it any; and after the work was complete, it took several weeks to get the frost out of the ground. After the ground was back to its normal temperature, there was not a particle of noticeable change in alignment of shaft.

I am confident this process must, in the near future, come more into use, as it only needs to be understood to be appreciated.

There has been some discussion as to the form of foundation to be used in our city. I find that in some of our large structures, engineers and architects have used the pile plan. This, I have no doubt, is a good one, provided they are of the right material, and properly driven. But it is wrong to call a pointed stick stuck in the ground a pile.

Among the successful pile foundations put down in this city, I would mention that under the Illinois Central Depot at Twelfth street by our worthy president; the new Stock Exchange building on La Salle street, by General William Sooy Smith; the new Public Library, and others I need not mention, the results of which are clearly to be seen.

We do not all agree on all things. In my opinion the most important feature in any structure is its foundation. We are all doubtless familiar with the parable of the foundation given in the Old Book. This has been amply demonstrated in the structure across the street north of us. Had the injunction given been lived up to, we should never have heard of people offering $47,300 for the privilege of removing the wreck. This building, like some others in the heart of our great city, that are built on the soft bottom, is very similar to a scow with a building on its deck—the steel beams and mass of concrete being its bottom and only waiting a favorable opportunity to be towed to some desirable location; failing in this, they spring a leak and settle. In the near future, rumor has it that there is to be a new post office or government building, built on the site of the present building; and this, if the present building is any

FIG. 105. FROZEN WALL, EIGHTY FEET BELOW THE SURFACE—SHOWING FRACTURE OF FROZEN QUICKSAND, TOOL-MARKS AND BOULDERS IMBEDDED IN QUICKSAND.

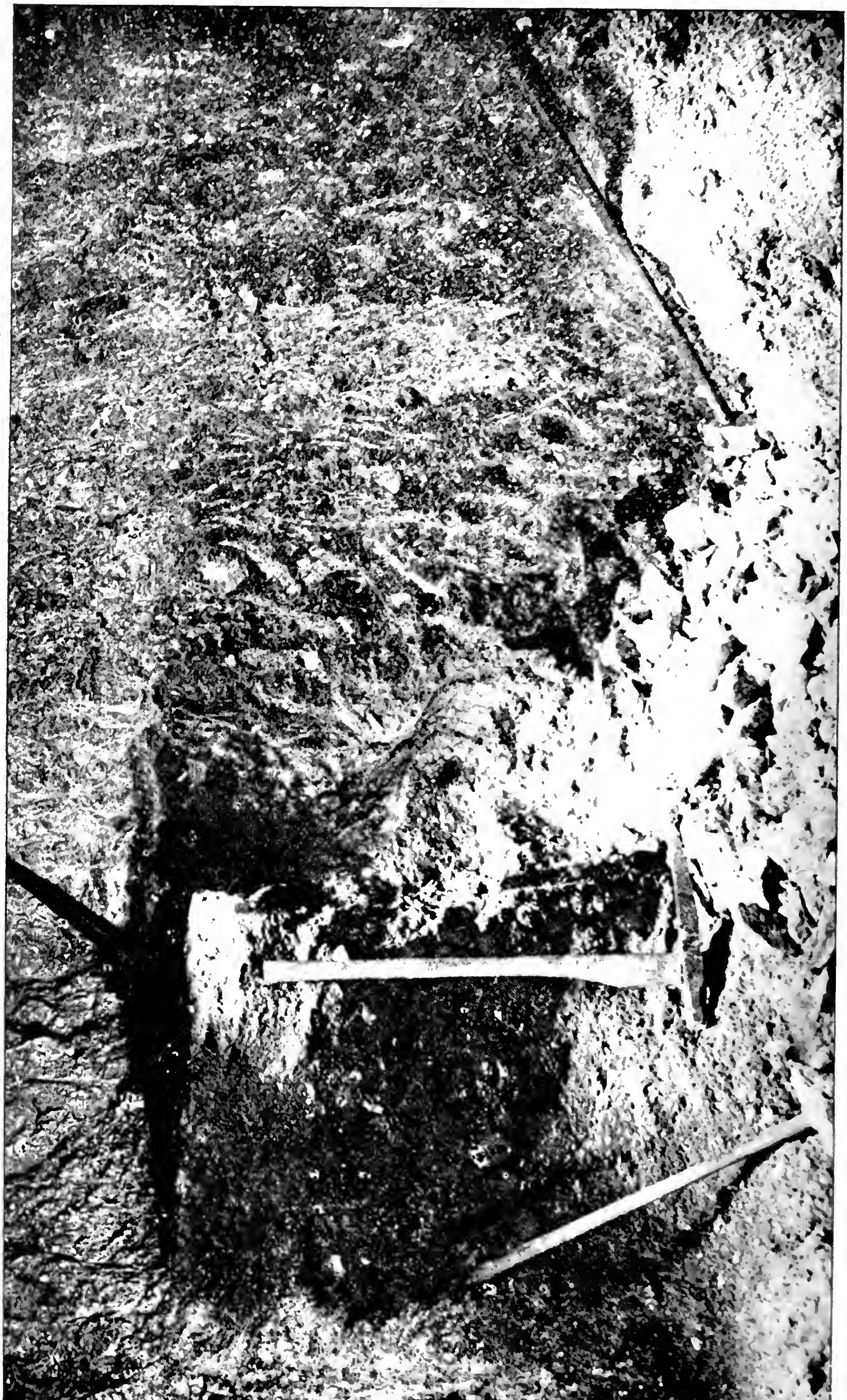


Fig. 106. Frozen Wall, Eighty-Five Feet Below the Surface—Showing Drill-Hole in Quicksand After Blasting.

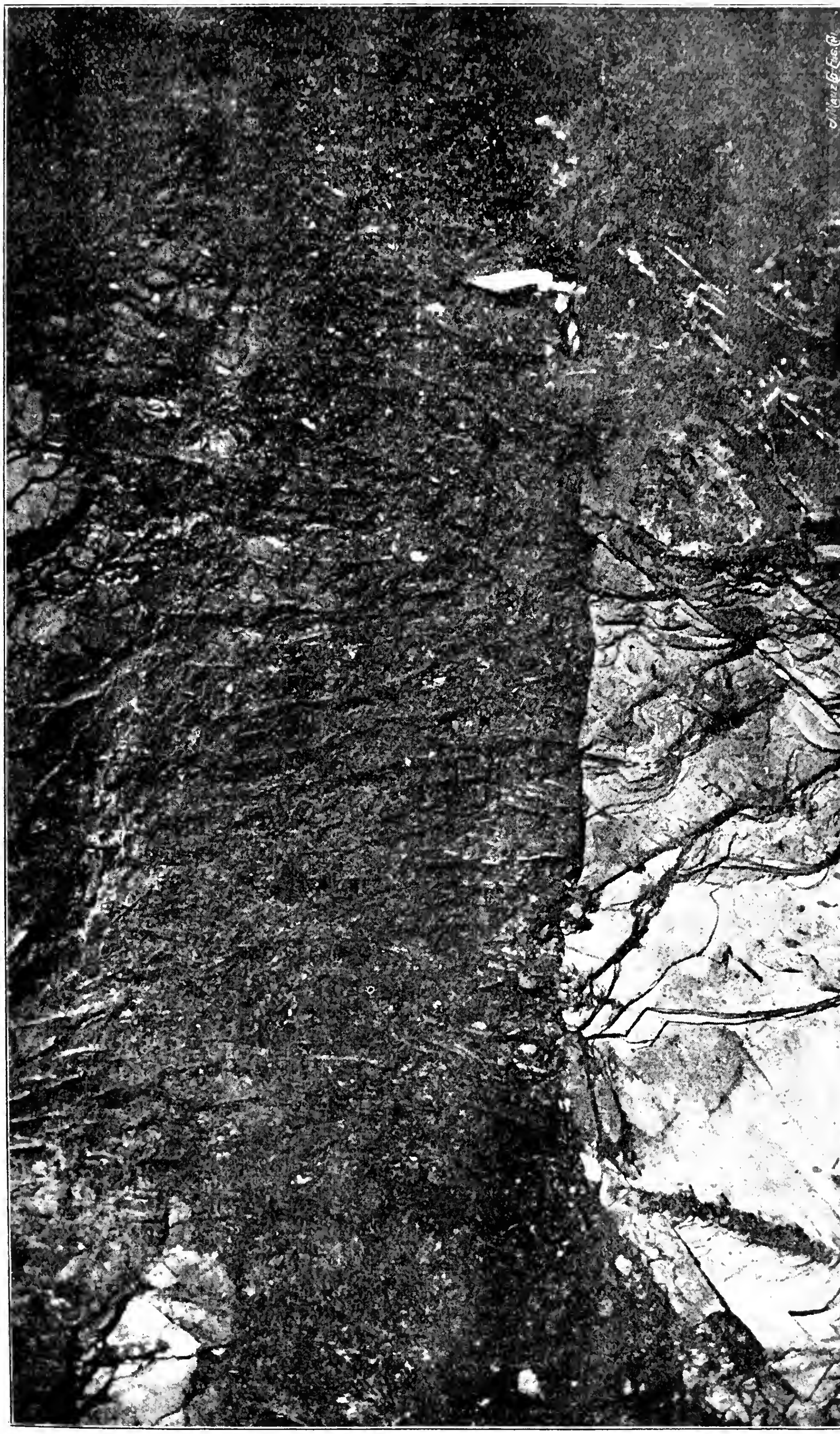


Fig. 107. Junction of Frozen Quicksand and Rock Ledge, Taken Ninety-five Feet Below the Surface.

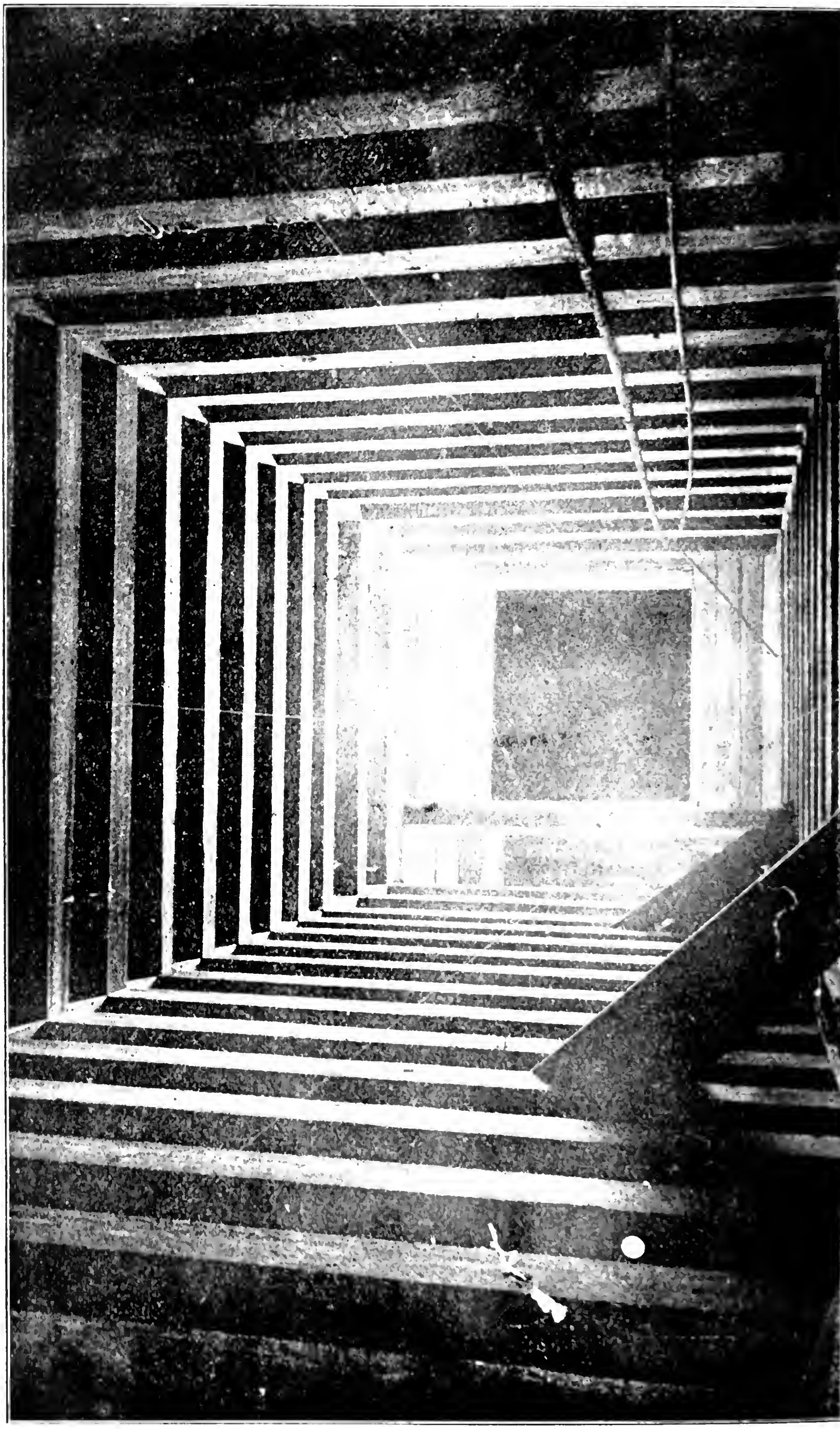


Fig. 108. Looking Up the Shaft—Showing Perfect Alignment of Timbering.

criterion, will need a foundation. The present building seems to be dissatisfied. There seems to be a rupture, a disintegration; all crying out to us to Note the folly of my founders, and take warning! This I hope will be done, and that our new building will show to the world that Chicago can, and will, put up such a structure for beauty and strength that in the ages to come will be a credit to the architect and engineer.

I see no reason why there cannot be such a foundation put in for this building that will carry it absolutely without settlement. The distance down to the stratum of absolutely safe carrying material is not to exceed sixty-five feet. We could either do this by pneumatic or the freezing process, and know for an absolute certainty what we are doing. Either of those systems are not expensive when we consider the result. The load allowed on floating foundations by engineers who have made the subsoil of Chicago a study, does not exceed three thousand pounds per square foot. With a foundation put in by either of the before mentioned plans, would allow a load equal to the crushing of the stone entering into the construction.

However, we cannot be of one mind on our substructure, any more than we can on the money question.

One thing we should do, whether our foundation be pile, pneumatic, concrete or any other form, let us do our best, and be willing to pay such prices that will enable the engineer or contractor to do just and honest work.

In 1889, I was sent out to the extreme east of Maine, to put in a light-house in the Bay of Fundy, about a mile and a quarter from the main land, for the United States Government, at a place called Lubec. From the boring made previous to the contract being let, the Light-House Board concluded to build this house on a cylinder, thirty-two feet in diameter, and about forty-eight feet high. Fill this with Portland cement concrete, and on this build an iron shell for house, backing this with brick, set in Portland cement mortar.

Specifications read something like this: There is seventeen feet of water at low tide; the cylinder must be dredged down about five feet through soft mud and gravel to hard pan; then put in seventeen feet of submerged concrete; then pump water out of cylinder, and put in remaining concrete, bricking up water tanks, etc.

Previous to putting in any concrete, I made a boring and found that there was not anything like hard pan to be found there. I at once notified the engineer in charge that I did not think it safe to put the house up on such a soft bottom.

Major Stanton, who had charge of this district, came down to Lubec, and we made a thorough examination of the subsoil. This he found to be as represented by me. I made several borings, and put the bit down ninety-six feet, mostly through clay, with some gravel. After the Major had consulted with the board at Washington, they concluded to have me drive piles on the inside of the cylinder. This was more easily talked about than done, having a

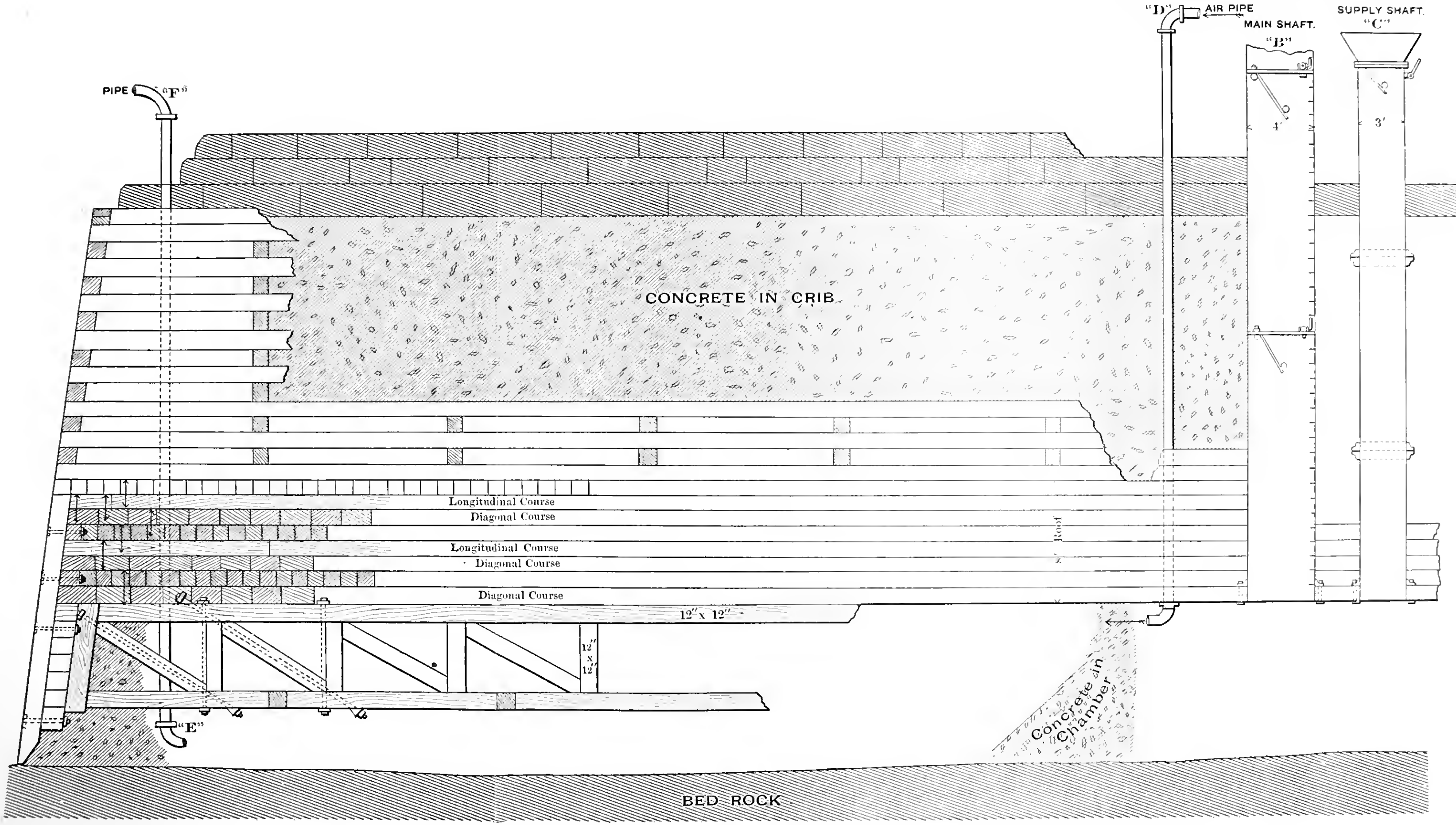
fluctuation of over twenty-four feet of tide, and a terribly rapid current, besides the storm and fog at that end of America to contend with. However, with all those difficulties we put in over two hundred piles, a large number of them being seventy-seven feet long when driven. Those were made of two sections. After driving the first section, we sawed the butt off perfectly true, put a dowel in the head of this, and brought the point of the second section to meet this, taking care in our selection of those sections to have them as near uniform size as possible; then bolting up and down the joints fish plates of oak. The first thing to be done was to get a pile driver and engine up on the top of the cylinder. This we did very successfully. Some days we would only drive one or two piles; then the sea would come up and break over us, compelling us to wait for better weather. But fortune favored us, and we finally completed this foundation. We also completed the whole structure.

During the progress of our pile driving, I received instructions to test two of those piles, driven at a given distance from each other. This I did in a way that there is no doubt of the result being correct.

We put a platform around the piles, and on this we loaded Kent ledge or pig iron, weighing every nail and scrap of timber and iron, knowing exactly the carrying capacity of those piles. Pile No. 1 was fifty-two feet long, sixteen and one-half inches in diameter at the butt, eight inches point, had a penetration of thirty-four feet into the clay. This pile we loaded with forty-nine thousand seven hundred and fifty pounds of iron. There was no change or settlement from the 13th of the month to the 20th. For the next six days it settled very slightly. In the first twenty-four hours, one-eighth of an inch; in the next twenty-four hours, three thirty-secondths until it stopped on the sixth day. Pile No. 2 was driven the same day, and allowed to stand one week before loading. We then put on this one (keeping the other loaded) sixty-five thousand five hundred and eighty-five pounds of iron. This one started down and went four and one-half inches in the first twenty-four hours, and in the next twenty-four hours only one-half inch. I then reduced the load one thousand one hundred and seventy-three pounds, the pile settling seven-sixteenths of one inch; and so, until I reduced the load on the third day, one thousand nine hundred and thirty-nine pounds. The piles still kept settling. I again took off one thousand two hundred and eighty-nine pounds. Thus, you see, I reduced the weight four thousand four hundred pounds. After taking off this amount, the pile stopped settling, but it still left us an excess over the other pile of fifteen thousand eight hundred and thirty-five pounds. This can be accounted for in this way: Pile No. 2 being seventeen inches butt and eight and one-half inches point, penetration was two feet greater.

I am satisfied the second pile settling was the means of taking the first one with it, as the settlement of the two piles stopped the same date. I am in favor of large piles, especially when they can-

Journal of the Western Society of Engineers,
Vol. 1, No. 4. Fig. 109.
Thomas--Deep and Difficult Foundations.



AN OLD-TIME CAISSON.

not be driven to rock or hard pan. In this way we get a greater friction, consequently more carrying capacity, but in every instance would advocate driving to hard bottom.

I am satisfied from tests made by General William Sooy Smith and our worthy President, and other prominent engineers, that we can put in foundations here, if proper care is taken, that will carry our tall buildings, or any other superstructure that we may want to put up, even a post office.

And would say that we should stand up as much for the engineers in this building to be erected in our city, as has been done for the architects. I think that stability is as much, or even more, than beauty. I care not how beautiful you make it, with a faulty foundation, the structure must settle, and be a menace and bill of expense to the owners, as was (and I think is) our Board of Trade building.

I visited one of our sky-scrapers a few days ago, and notwithstanding the fact that this building is not one year old, the walls are cracking, and, as it has no tower to take off, I don't know how the weight can be reduced.

So, be careful of your foundations.

DISCUSSION.

Mr. Thomas—I have some photographs here of the freezing work done at Chapin mine, Michigan, and one of the Manhattan Life Building. We went down 50 feet below the grade of Broadway with our foundations for that immense building. The tower on the building is about 70 feet higher than Trinity Church steeple, which stands across the way. You can form some idea of the height of the building from this.

Figure 109 represents an old time caisson. I brought it here for the express purpose of explaining to the younger members of our society.

"B" is the main shaft, and the one the workmen pass in and out through. You see every section of our shaft is a lock in itself, consequently we never have to remove lock to lengthen the shaft. Our doors are all made to fit any section of our shaft. All doors open inwards. Every fifteen-foot section of our shaft is ample to allow every man working on the inside to be taken out at one time. "C" is the material or supply shaft, through which we take all materials that cannot be blown or pumped out. We also fill the working chamber with concrete through this when the caisson has been landed.

"D" is the pipe through which we are supplied with air from the air-compressors. On the lower end of this pipe we have a clapper, in event of our hose connection being in any way detached. This will at once close the opening and keep the air in the caisson.

"E" is one of the blow-pipes of which there is a number. Through the caisson those pipes can be used for either blowing out

sand, gravel, or we can attach to them mud pumps for soft material. The reason we put in so many pipes is to save moving the materials any distance. "F" is the "goose neck," and is used to divert the material blown out. The mottled coloring on top of roof shows the concrete filling in crib, and that below the roof shows filling in working chamber, thus indicating the amount of timber between the concrete. This amount will allow considerable compaction, hence I claim the less timber entering into roof the less the shrinkage; the shrinkage due to large quantities of timber is the cause of the cracks so often seen in bridge piers.

The plans used in the years gone by show you that we did not know it all then as we do not now, but we know a little more than we did twenty years ago.

Mr. Reynolds—Are all men who work in caisson affected the same?

Mr. Thomas—No, sir; they are not all affected the same way. Almost anybody can go into compressed air if they are built the right way.

Mr. Reynolds—Did you ever find anyone that could not go?

Mr. Thomas—Yes, I found some men who have inflammation of the inclination; those do not want to go in. I never found a man that could not go in provided that he would do as he was told. I have found men that I would not allow to go in. I never allowed any of my friends to go into a caisson unless I went in with them myself, and whenever I took a gentleman or a lady in there I always compelled them to take hold of my hand when going through the lock; in that way I could tell the condition of their heart.

A Member—I would like to ask where timber caissons have been used like that, as in the design shown, what has been done to make the roof thinner? What is Mr. Morison's plan?

Mr. Thomas—The first work I ever did for Mr. Morison was to put the foundation down for Plattsmouth bridge on the C. B. & Q., and there Mr. Morison used one single cross course of timber on the caisson. He simply used one horizontal cross timber between the concrete on which the masonry rests and the filling in the working chamber. He also fills between the inner and outer walls of side of caisson with concrete, thus transferring the weight from center of roof to sides of working chamber.

Mr. Gerber—Mr. Thomas said that in sinking the Plattsmouth caisson they went down faster than any he has ever known before or since. I would like ask him what the rate of sinking was, and also how many cubic yards per day were excavated.

Mr. Thomas—I started to sink those caissons—I think it was the 1st day of September when I put in our force first—and on the 30th day of December I had finished everything going down with the caissons—one 35, one 55 and one 75 feet. We averaged eight feet in 24 hours every day that we were sinking; there were quite a number of days that we could not sink; could not keep up with the concreting.

Mr. Gerber—Do you know what the cubic yards were?

Mr. Thomas—I am not prepared to answer that question now. I have a statement of it.

Mr. Gerber—Mr. Thomas speaks of the desirability of reducing the thickness of the timber over working chamber there to a minimum, on account of the possible compression, and he also mentions the kind of caissons built by Mr. Morison. If the gentlemen are interested in the exact details of those plans, there are several of Mr. Morison's reports in this room which would show them.

Since Plattsmouth caissons were built, Mr. Morison has adopted a somewhat different plan in which there are two feet of timber over the roof. In 1883 the Blair bridge was built with the caissons on the plan which we have used ever since, with two feet of timber over the roof. In one of the piers which was built on the shore when it was placed, and was subsequently in the river, although the caisson did not move. We had a peculiar experience which possibly illustrates the compressibility of the timber. When the bridge was completed to my personal knowledge the pier was carried up plumb. About a year after the bridge was completed, while I had charge of the work, we had occasion to build a large embankment, the slope of which was fifty feet west of the pier. Before this embankment was completed the ground on either side bulged up and the embankment settled, the greatest amount of settlement at any one time being six feet over night. At first the rising up of the ground took place on either side of the embankment; but, as we continued filling, it pressed out into the river, and some distance north of the pier there was a decided breaking of the surface, showing that the earth was moving towards the river, and of course exerting a great pressure on the pier. The settlement of the embankment and maintaining of traffic over the embankment at the same time was rather interesting, so that I paid comparatively little attention to the pier, but I discovered one day that a space where we had, under ordinary conditions, six inches between adjoining spans, we had only about one-half inch, and on making careful examinations I found that the pier next to the shore was out of plumb, and the only way we could account for it was the compressibility of the two layers of timbers between the layers of concrete.

Mr. Thomas mentioned another thing, that the caisson must be built strong enough to resist the pressure of the material through which caisson was being sunk, etc., when the air was all blown out.

In 1887 in sinking one of the piers of the Sioux City bridge we were nearly at the bottom, and the bottom of the caisson was about five feet in the clay. In order to get it down the last two or three inches we blew out every bit of air and did not get more than an inch or two of water in the caisson, so that we had the whole pressure on the outside to take care of.

The reason I ask Mr. Thomas as to the rate of sinking, probably as rapid sinking as ever has taken place. which was under Mr.

Morison's direction, was done at Cairo, where I think a caisson was sunk 20 feet in three consecutive days, and that was done by working nights only. The excavation in three days amounted to 300 cubic yards per day. I may have got that figure mixed up somewhat with Bellfontaine bridge, where there was also some rapid work, but at that point the difference in the amount excavated in 24 hours was not very great; only in one case the full 24 hours were worked, and in the other case only about 12. That excavation was done entirely with the Morison sand pump which is operated by water, and instead of shoveling the material up to the pump, a long flexible hose is attached to the bottom and the material pumped up wherever it happens to be. The number of men required in either case is not materially different. The wearing out of the pipe, and the fact that soft material wears out less rapidly than hard, we found illustrated in the wearing of the more exposed parts in the sand pump, where we had to change it quite frequently. In the goose neck, by using curves of long radius, we have never had a great deal of trouble. A goose neck from ordinarily heavy iron pipe lasts a job out, but it is useless to carry it on to the next.

The caisson illustrated by Mr. Thomas shows a battered side, and I would like to ask what success he has had as between a straight side and a battered side. My own experience has been that a battered side is not as good as a straight side. We had a battered caisson at Sioux City which went down like a cork-screw.

Mr. Thomas—My experience with the battered or square, I have never had much difficulty. When I put the caissons for the Chicago and Alton bridge at Glasgow, some years ago, we had considerable trouble there in holding the battered caisson, due to scouring out of material under cutting edge of caisson. I went down at Philadelphia on the Schuylkill river through a marsh, with a plumb caisson, and it seemed to me that I had more trouble holding that caisson there in position than I had with a similar caisson on the Harlem river with a batter. That may have been due to a pressure that I could not control. I do not think it makes much difference whether battered or not.

A Member—Mr. Thomas has spoken of the difficulty in sinking caissons at Cincinnati through wrecks of steamers and raft logs, and bottles and other fossils. I would like to know what method the contractor takes to get rid of such obstructions in sinking caissons, and what size he has to reduce them to really get them out of the chamber? What method do you take to dispose of it.

Mr. Thomas—I presume you mean the obstruction that is not suitable for filling. Years ago we had to pack that all out in sacks through the lock, but as I stated, I found Mr. Morison, Mr. Moran and Mr. O'Connor had devised a scheme whereby we could take out such rubbish in excavating locks, but when we get near the bed rock, where we often have boulders and loose rocks, we naturally get the benefit of the load, and do not take them out,

but we pack them up on the braces, and when filling build them into the concrete in the chamber.

Mr. Kellogg—Speaking more particularly of the logs.

Mr. Thomas—We split the logs up and pass them out through the material lock supplied for this purpose. There are three of those in use, viz., O'Connor, the Moran, and the Morison.

Mr. Gerber—I might add that in describing the lock which has been used and is illustrated there, that the lock which Mr. Morison has generally used is one which has its doors hung vertically, and the doors can therefore be handled very easily. The lock is like an ordinary room door, in the shape of a rectangle, which has on each side a semi-circle ; the rectangle is divided into two square chambers, one of them receiving the shaft from the bottom, corresponding to the bottom portion of that shaft, and the other generally carrying the shaft to the top. The doors open from the semicircular portion into the down shaft, and also into the up shaft, and we find that that lock is a very convenient one, more particularly as it has two sides to it so persons can pass in either direction at the same time, and if one side should by any means become impassable, there is another one that we can go through.

As for getting in cement, we never use the material lock for getting in cement. The old fashioned way has been good enough, and although we lose a little more air, on the whole it is a little quicker.

Mr. Thomas—You keep your lock at the bottom of the shaft, the air lock I refer to?

Mr. Gerber—Yes.

Mr. Thomas—The objection I have to that is that in case of an accident there is not as much opportunity to get out as when we have a lock above.

Mr. Gerber—The accident usually comes at the other end of the lock.

Mr. Thomas—I never had but one accident and that was at Havre de Grace. I was born once and my birthday comes along every year, I had been very busily engaged and General Smith thought I ought to get off and have a holiday and I went to New York. During my absence, I left instructions with a subordinate what to do as the caisson went down. Well, it seems that between two stools you go to the ground. There were two people that had to look after this work and they neglected it, and, as a consequence, the man who had charge of the sinking, sunk more than he ought to have done. The consequence was that he got the caisson so far down that the shaft and lock were submerged, with seven men inside. Well, it so happened that I got back that morning from New York, and I inquired if certain things had been done, and my boatman told me no; I had a presentiment there was something wrong, and we went over, and just as we got down to the island, the accident happened. I got on the work and it took me just five hours, not myself alone, but General Smith and Colonel Patton, with the aid of the workmen to get those men out. Now, if we

had had the lock in the bottom of our shaft, I doubt if we had ever got those men out alive. They were in seven hours as it was. We devised a cofferdam on top of that shaft; I put some posts on top of the shaft and some canvas around those; also, quick-settling cement, and put that in bags and packed it around the joints; then bailed out the water and in that way we got the men out. If our lock had been down 90 feet, I doubt if we had ever got the men out alive.

Mr. Gerber—In regard to that I believe it is better to have the lock at the bottom.

In Omaha we had an accident in which the shaft filled up at the top before we noticed it. In attempting to get out, somebody discovered that instead of the air rushing out of the escape valve in the usual way, a good deal of water came in. I believe at the time they had telephone connection with the caisson and when it was discovered what the state of things was the men were informed of it and were directed to keep cool—a caisson is not a good place to keep cool in. Pumping appliances were immediately provided and the shaft was pumped out, and when the shaft was nearly pumped out the balance of the water was locked through one of the locks without any injury to anyone. On the same day about the same time a similar leakage took place on the Rulo bridge, that was discovered much quicker than the other one and with no serious result and the men were not kept in any number of hours, whereas at Omaha they were in several hours.

Mr. Goldmark—It seems to me that one advantage in having the lock at the bottom is that any apparatus for hoisting men out could be more readily arranged for. I know the old methods have been used with very great success.

I want to ask Mr. Thomas as to the truss that has been shown below there, what his practice has been with regard to using a heavy truss inside of the chamber. I know that at Kansas City when the Winner bridge was built Mr. Jenkins made a design of a very strong truss through the center of his caisson, and he put them very close together, and he told me that he considers them an absolute essential for safety in any caisson, that he considers any caisson without any such heavy truss as dangerous, and he says that several times he has saved his own life, or at least the life of his men, by having such a heavy truss. Now, at Kansas City, Mr. Jenkins was designing engineer, but was not afterwards the constructing engineer; one of the first things the constructor did was to cut out this truss which he considered very much in the way, and of course it is. I would like Mr. Thomas' opinion on that.

Mr. Thomas—You speak of Mr. W. D. Jenkins?

Mr. Goldmark—Yes.

Mr. Thomas—I do not consider that there is any necessity for a truss in a caisson where the span is not too great for the deflection of the timber, and I do not think I can answer it in any other

way. The truss is simply put in there to sustain the load. For instance, take a 12 x 12 x 40 foot timber, there is a great deal of deflection. That truss simply stiffens up the floor beam. As you say, the truss is an obstruction and it can be gotten along without if you bring the line of thrust in here (indicating). The more clear way you can have in the working chamber the better.

Mr. Goldmark—Without the truss there is a weak place in here (indicating on diagram), and a tendency to break through.

Mr. Thomas—Never saw it in my life, and I have done more of pneumatic work than any man in the country. The first I ever used was at Havre de Grace; that is where Col. Douglas was Chief Engineer, and Col. W. M. Patton was in charge, and Mr. Jenkins was an assistant.

A Member—Mr. Thomas speaks of the ninety-foot shaft that he had in one caisson; I would like to ask how he got his men in and out of that shaft—in an elevator?

Mr. Thomas—No, sir; only a ladder.

A Member—I know that Mr. Morison has used in some of his later work an elevator or lift for the men, and I believe that that has been claimed to reduce the trouble of caisson sickness considerably. I do not know what the details of that elevator were at all.

Mr. Thomas—I have never used any other means than a ladder, but I have urged the advisability of having an elevator. There is more danger in a man getting out and his getting back to the natural condition; that is the time that he has to be most careful of himself; it is the exertion of climbing up a long shaft that does more injury than anything else, and an elevator is a very essential thing in pneumatic work.

Mr. Gerber—The elevators were used at Memphis and also at Bellefontaine; the shafts, as I remember them, were six feet in diameter; on opposite sides there were two steel guides, and on these steel guides ran a very simple sort of a platform suspended from a wire rope; the platform was hoisted by means of an engine on top of the shaft, which was operated by compressed air from below, one of the objects of using compressed air being to provide an additional means of ventilating the caisson. In the case of Memphis, the lowest depth reached was 108 feet below water, and the elevator proved of great advantage in bringing the men up from that great distance. Of course the distance from the bottom of the caisson to the roof being about 8 feet, the men had to climb that first, and possibly ten feet more before they got to the elevator, the rest of the distance they were enabled to go by means of the elevator. I think that the elevator was used in the two river piers at Memphis, possibly three of them. At Bellefontaine it was used on three out of five; I think the two smaller ones were sunk without the use of the elevator. The material lock which Mr. Thomas speaks of is also operated by compressed air, which gives means of ventilating the caisson.

Mr. Reynolds—I would like to ask in reference to working in

the quicksand, what effect did blasting have on the rest of the material?

Mr. Thomas—Well, it did not seem to disturb it at all; we never had any trouble; where we put a blast in we would drill down, and it takes as long to drill a hole in the quicksand as in ordinary sandstone, but the boys soon discovered that a little chloride of calcium, as a lubricant, made easier drilling. When we fired our blast we were very careful at first, but after a few weeks we found that we need not take that care; we never had the slightest trouble with our blast.

Mr. Reynolds—How did you make your test through that quicksand—tensile test?

Mr. Thomas—I made the test down in the shaft, because I needed to test that at the temperature that it was used in the shaft. I got up an appliance, took one of Fairbank's testers down in the shaft with me and I got up a plan of my own whereby I could apply a compressive strain with that machine, as well as a tensile one, and I tested everything in that way. I made a test as I would test cement, and I made a reverse lever, so that I got the compression with the same lever on that machine. I also submitted it to a test in the house, but that was not as good as that down in the shaft.

The Chair—I would like to ask Mr. Thomas if, in sinking this shaft by the freezing process, whether there was any leakage in the shaft after the sinking commenced?

Mr. Thomas—Yes, we had trouble with one pipe, and it was due to this cause. The 8-inch pipe was put down by the Chapin-Mine people before the time we had charge of the work, and they landed one of the pipes on a small boulder, and when we got down to it found that this boulder had cut off the freezing effect, and allowed the water to come in under the boulder. We got down about 80 feet without any trouble, finally I found I was getting a little water there, I bailed that out; the water that we got the first day did not amount to much; I bailed it dry with a bucket very soon, and I thought I would stop to see if the freezing would not check it, but it did not. Then I put a small pump in and that did not remedy it. I put in an auxiliary pipe right over the leak, with a return bend right on the end, and got that right down to the sand, and connected this pipe with the circuit, and in the course of a few days I found that I shut off the leak entirely, and made a perfect success in building that shaft.

The Chair—I have a question or two that I would like to ask in addition to those that have been asked. One is with regard to the loading of foundations in the city of Chicago, spoken of by Mr. Thomas. Have there, that you know of, been heavier loads than 3,000 pounds per square foot on earth foundations in this city?

Mr. Thomas—Yes, I think in nearly every case they have loaded more than that. I know they have in the Auditorium and the Auditorium Annex, and the annex tells the tale to-day. They

put in some beautiful floors when they put up the building, but they are taking them out now and putting in something to hold the building up. I think they loaded 4,000 pounds in the Auditorium.

Mr. Reynolds—Do you know how much they loaded in the Masonic Temple?

Mr. Goldmark—I think that is about 3,000 pounds; I think Mr. Shankland has used more than 3,000 pounds. I think in the Masonic Temple the little difference in settlement results from the fact that it is a rather large area, and the buildings that stood there before the Masonic Temple were of course of different shapes and different times and part of the surface was not built on at all on account of courts, and there was some previous compression of a part of the soil.

The Chair—I would like to ask, in the test piles driven in the Lubeck light house, how close together were those piles?

Mr. Thomas—With reference to the test piles?

The Chair—Yes.

Mr. Thomas—They were about six feet, just six feet from center to center they were driven.

The Chair—And what plan did you adopt in determining the settlement, how did you make the measurements?

Mr. Thomas—I put a graduate on the face of each pile, and from the side of the cylinder an iron bar; I put a bar up straight, and then I brought out an arm at a right angle with it, and brought it down to a fine point; we did not have a rule, but the graduated measure was put on the front of the pile to the point of the needle, so that there was no chance for any deviation due to settlement without our knowing it. The Government was paying for it, and of course I did the best I knew how.

Mr. Kellogg—I do not call to mind where I got the old formula, but it has been used for pile driving, especially friction pile, the rule of one ton to the square foot surface. That is a very short rule, I suppose that is providing that a friction pile be factored according to the material which it penetrated, and they use this for sandy gravel a ton to the square foot of surface of the pile, not of the diameter of the pile, of course; a smaller pile would have a smaller surface, after it was in a certain distance, say ten feet; I found it worked out in practice—with a "factor of safety," and I find these test piles stood a little bit more than that.

Mr. Thomas—I do not know. I know quite a number of formulas, but I do not know any two that worked out alike. It depends entirely upon the soil they go through and the penetration, etc. I have made borings here in Chicago and have worked all day and not got down six feet; I have worked a very short time and got down farther than I wanted to go; the more rapidly I got down with my augur in boring, the slower I got a pile down, and I do not know of any formula whereby I should feel safe in saying what load should be put on a pile; I think there is nothing like a test.

Mr. Goldmark—It seems to me that a ton to a square foot is a very great strain. I do not think even in larger caissons or in smaller bodies sinking through soil, that any experiments show more than half a ton the maximum, as a frictional resistance. Perhaps Mr. Kellogg can throw some light on where that formula came in.

Mr. Thomas—If you put a pile on sand and constantly agitate that pile, stand at the head of the pile and get up a movement, you can send it down better that way than by striking it.

Mr. Kellogg—It occurs to me that the reason for the settlement of the pile that you were examining, was caused by the waves of the stream having shaken the pile.

Mr. Thomas—The test piles that I tested were inside of the cylinder.

Mr. Kellogg—I know that the agitation of a pile after it has been driven, will get the pile down better than merely with the weight of the hammer; that the shaking of the scow will start it again. But as to the formula I was speaking of, I will try and place it; I do not know whom it is by; my memory serves me right as to the element of calculation of the bearing power. As for a factor of safety, of course, a man must take according to his judgment whether it is a quiescent load, or whether it is serving under a railroad train.

A Member—I would like to ask Mr. Thomas in regard to temperature in the bottom of the shaft that was sunk.

Mr. Thomas—Well, the temperature in the bottom of the shaft is about equal to the temperature of the frozen ground; but it varied; I think the lowest we got is about minus 29 at the bottom of our shaft; it varied down on the bottom. The workmen worked with their coats on comfortably, but I think the lowest we got is 29 Centigrades.

X.

RELICS TURNED UP IN THE DRAINAGE CANAL.

By Ossian Guthrie, M. W. S. E.

Read August 5, 1896.

Mr. President and members of the Western Society of Engineers:

Your committee on publication has assigned to me the task of preparing a paper on "Relics Turned up in the Drainage Canal." This title would seem to be broad enough in scope for an interesting and valuable paper, but the multiplicity of incidents which have occurred, the number of changes which have taken place and the number of things which have turned up during the eleven eventful years just closed (all of which are piled in my memory in confusion) render it difficult for me to select and arrange the matter in a satisfactory manner. It so happens, and accidentally so, that the special committee of the Citizens' Association appointed to investigate and consider the effect of the great rain of August 2, 1885, upon the main drainage and water supply of Chicago, entered actively upon its duties eleven years ago to-day, and here is what was then observed: "On Wednesday, August 5, the river discharge was observed in an unbroken stream to and around the crib." On Sunday, August 2, 1885, $6\frac{1}{4}$ inches of rain fell, the real significance of which, beyond the flooding of basements and consequent damage to property, was little understood; but there were those among us who thought they saw great possibilities in the calamity, for it was in this light only that the average citizen viewed it.

On Monday, August 3, the special committee above referred to was appointed, entered actively upon its duties on the 5th and published its report in the daily papers on the 27th of the same month. Ever since then some of the members of that committee have watched the progress and promoted the welfare of the great work which has resulted with unabated zeal. Your committee did not ask me to tell what had been turned down, but I have volunteered to tell. Not one of the original promoters is to-day officially connected with the enterprise. Early in the progress of the investigations of the committee, and while visiting the Dolese and Shepard quarry in Cicero, where a large area had been recently stripped to get the soil for the park, there was exposed to view some very interesting and instructive glacial markings with the boulders undisturbed. Among these grooves one was found about 75 feet in length where the granite boulder which had cut it still remained in the unfinished groove. This incident led to a careful and thorough geological investigation and the preparation and publication, by the writer of a geological description of the valley through which the drainage channel is being excavated. This description was so much at variance with earlier geological reports that unusual interest has been developed which has resulted in careful investigations being made as the work progressed. Those investigations brought to light

many interesting features and furnished conclusive evidence that this valley was the main pathway of one of the most stupendous glaciers which the Creator had ever set in motion. This glacier, which had originated in Hudson's Bay and extended south below the 38th parallel of latitude in Illinois, had gathered and incorporated within itself rocks and debris from an area of possibly a hundred thousand square miles. Upheavals of igneous rocks had paid so bountiful a tribute to its demands as to become a conspicuous feature of the glacier itself, long before it had reached this latitude. These rocks were set like diamond cutters in a glacial matrix of such depth as to give, possibly, a pressure of 2,000 pounds per square inch upon the bed rock. This glacier, it seems fair to assume, moved with comparative rapidity, for, if it moved at all, with such a cross section as Lake Michigan would show, it must have moved more rapidly when contracted to the limits of this valley. If we can conceive such a glacial mass so equipped with cutters, and moved by a gravity force almost without limit, we can readily see how 500,000,000 cubic yards of limestone, or even a great deal more, rock could have been disrupted, ground up, and dispersed, within a distance of forty miles along this line, which it is estimated was done. In a paper read before the Chicago Geological Society May 19th, 1893, the writer gave the following as his definition of a glacier:

A GLACIER.

"A glacier is a river of compressed snow or crushed ice possessing such cohesive qualities as to give it the appearance of solid ice. Many writers attribute to glacial ice, plastic or waxy qualities, but these words do not seem to convey a correct idea; however, that expression which best conveys the idea that glacial ice is capable of changing in form, widening here and contracting there, in conformity with the valley through which it moves, is perhaps the better one to use. The glacier moves by force of gravity, and consequently its surface always slopes in the direction of its movement, but its bed may be ascending or descending, or alternate; but the mean between these must always be inferior to the slope of the surface."

It would now seem to be in order to tell, specifically what relics had been turned up.

In the course of the engineering investigations and during the progress of the work, it has been found that where the floor of the valley had been protected from the elements these glacial striae were found; and always in the direction of the valley, except at the Sag junction. At this point the glacial streams, in some degree, seemed to influence each other. At Lemont, where the protection had been light, the glacial grooves, although weathered or water worn, were clearly shown. At this point the valley is over a mile in width and the minimum depth of the strata of rock removed by glacial action is easily determined, but the maximum

probably greatly exceeds this. It has been demonstrated by actual measurement that at least twenty-eight feet in depth have been removed from the valley at this point where the lightest cutting was done, by some agency, and we have no evidence that another force was at work in this line before the glacier, as all previous conditions were obliterated by the ice stream, while the erosion by water since the close of the glacial period (about 8,000 years) does not much exceed two per cent of that by glacial action. During this same period, the accumulation of silt and vegetable matter outside the water course far exceeds the capacity of that channel. A poor showing, indeed, for an agency heretofore credited with the erosion of the whole valley.

Joliet Mound, which is located on the north bank of the Desplaines valley below Joliet, is described in the Illinois geological reports as an alluvial deposit, etc., and the story is then told that workmen taking out gravel found a live frog, which hopped away, and another story is told of finding a flint-lock pistol in the gravel, ten feet below the surface. Joliet Mound is a glacial deposit and is composed of material ranging in size from very fine sand to boulders weighing several hundred pounds, and these are mixed indiscriminately from top to bottom. Had the writer, above referred to, taken the trouble to investigate the bed and opposite bank of the valley, he would have found the most conclusive evidence of his error in relation to its alluvial features. At this point in the valley, the great glacial plow seemed to have a double mouldboard which turned finished glacial material over to the north, forming Joliet Mound, while the other, to which the share seemed to have been attached, was cutting a furrow possibly forty feet in depth in the solid face of the rock, and either turning the freshly broken fragments over upon the plateau above or carrying them forward to perform other functions. In the spring, when there is neither foliage nor weeds to obstruct the view at this point, it is interesting indeed. The writer feels justified in recurring to the frog and pistol story. Joliet Mound, as has already been stated, is of glacial origin and has been there 8,000 years, and the pressure upon the bottom due to its height, about 75 pounds to the square inch, would seem to be a "pretty tight squeeze" for the poor frog to endure for that length of time, to say nothing of the grinding process to which he must have been subjected before burial. As for the pistol story, there would seem to be some mistake about that, for the reason that the flint lock was invented during the 18th century. However, inasmuch as engineers are supposed to know everything, I leave these stories in your hands as I shall, also, the story I shall later tell about a trilobite. Along the lower end of the canal where the rock comes to the surface are considerable numbers of clay pockets—holes of various sizes, sometimes many feet in diameter and in a great many cases irregularly funnel shaped with the apex downward. These holes give evidence of having been made either by water action as limestone

caves, or by water and stone as pot holes, or they were originally caves and were enlarged by revolving stones in the bed of the glacial stream.

These pockets are filled with glacial clay in which are some foreign pebbles and many boulders—sometimes of great size, but often not much worn. Mr. Chas. H. Ford of the Calhoun School in this city, found in one of these pockets a considerable quantity of soft coal in small layers and patches. This coal appears to have been formed in the clay, although no adequate explanation for it has yet been presented.

At Chillicothe, on the Illinois River, there are immense deposits of sand, gravel and granite boulders; and now and then a copper boulder, or pebble, is found. Ebin J. Ward, an engineer of the Sanitary District, while surveying here, procured and presented to the writer a fine specimen of copper weighing 30 pounds.

Mr. Ellis Kiser, a reputable business man of Chillicothe, informs me that a granite boulder was found there a few years since which was sold for thirty dollars to a monument maker. In a great measure, those deposits, without any doubt, passed through the Desplaines valley by ancient or glacial transport, and now, after a lapse of thousands of years, sand is being shipped from there, back to that valley, to perform an important function in modern methods of transport. This sand contains less than one-half of one per cent of impurities.

RELICS IN THE ROCKS.

The oldest relics found in the work of the drainage channel are the fossil remains of the inhabitants of this region many millions of years ago, when this part of the continent was at the bottom of a shallow arm of the ocean. Among these I will only mention the trilobite, whose perfect remains are by far the most numerous.

Geologically this time was what is known as the Niagara period, the oldest of the upper Silurian.

During the progress of the rock work near Lemont, and after a successful blast, a very perfect trilobite was found, so perfect indeed as to suggest to the finder that life still lingered there. This trilobite was placed in a pail of water and left to revive, and when the finder returned to see what the water had accomplished, the trilobite was gone; leaving only a trail in the mud showing the direction of his movement.

The Fitzpatrick mound, which is located about midway between Romeo and Lockport, and at about the center of the valley, is the highest point through which the channel passes It is about 2000 feet long, 1000 broad, and between thirty and forty feet high. It is composed largely of limestone boulders and gravel. In excavating the drainage channel it became necessary to remove a strip from the east side the whole length of the mound. This excavation exposed to view a fresh clean cut face, which gave an excellent opportunity to study its geological character. This mound rests upon a glacial planed surface a few inches above the surrounding

rock surface, which has doubtless been worn away by the action of the elements. Upon the very top of this mound there are many granite boulders of comparatively large size, and in the face of the freshly exposed section these erratics may be seen promiscuously mixed and intermingled with the limestone boulders from top to bottom. These foreign boulders have, without doubt, at one time or another in their long and eventful journey, been doing service as cutting implements upon the bottom of Lake Michigan, nearly a thousand feet below the point we now see them. Mr. Fitzpatrick found a copper boulder here weighing 18 pounds, and seven pieces of pure copper, ranging in weight from one pound to 168, and aggregating several hundred pounds have been found in the valley between Summit and Joliet. Gold has been found on Sec. 1, and a fine specimen of silver, identical with that found at Keweenaw Point, Lake Superior, has been found a short distance up the sag. How were these erratics elevated? This question has been propounded and discussed by geologists from Agassiz to the present time, and it seems to me, in view of the following, I am justified in injecting it into this paper for discussion. On page 208 of Wright's "Ice Age in North America," Prof. Lesley says: "The only problem of prime difficulty is, how the ice managed to lift the fragments from the outcrop in the valley to the crest of the Kittatinny Mountains"—a problem which is repeatedly presented for our solution, etc., and again he says, page 219: "Still it remains a problem by what sort of internal movement a stone held in the ice can ascend, however gentle may be the gradient upward. In fact, our knowledge of how such an operation was performed is as vague as possible, and demands the attention of hydraulic engineers." The writer began his discussion of this subject in a paper read before the Chicago Geological Society, October 30, 1890, in the following language: "Nothing short of finding a law universal in its operation, by which every fragment of rock deposited upon the back of the glacier can be carried to the bottom—and in boulder form returned to the surface, and by which also every boulder and fragment collected in the valley can be elevated to the surface and delivered thence to hill or mountain top, or in due time deposited in the moraine, will solve the problem. The power required to accomplish this is inherent in the moving glacier, and results from the gravity force which moves the glacier, precisely as a river current is produced. The bottom and sides being retarded by friction, a rolling and sliding motion is produced which is the exact counterpart of the river current." To this I will now add: The friction at the bottom of the glacier retards its movement more at the bottom than the top, and the top is depressed and the bottom in the same degree elevated until finally the bottom reaches the surface, bringing with it rocks and debris which have become incorporated in its mass. This vertical rotation is as constant as the forward movement of the glacier. Friction retards the sides

more than the center, and consequently a double horizontal rotation is produced which is both a medium of collection and dispersion, but the latter is by far the more potent, as there is not only the lateral slope of the ice, but a constant flow of water conveying debris towards the lateral moraine. The proposition laid down at the start that the elevation of rocks, by glaciers, was the result of a natural law and universal in its operation is now, perhaps, settled beyond discussion. One argument adduced against the above theory of elevation, however, is that the large angular rocks are generally at the top of the glacier and are generally also found at or near the surface of the ground in a glaciated territory. To this I answer there is where they should be. If you will place large stones at the bottom of a box and small ones and gravel at the top, either with or without water, and then disturb them in any manner you choose, so long as you move the large stone at all, you will soon see them at the top, there to remain. The discussion of this subject incidentally leads us to the discussion of another, the "Medial Moraine." Wright, heretofore quoted, says: "If there be a current of ice on each side of the mountain-peak, two of the lateral moraines will become joined below the mountain, and will form what is called a medial moraine, which will be carried along the back of the ice as far as motion continues. As the ice wastes away toward the front, several medial moraines sometimes coalesce."

The medial moraine has heretofore been attributed wholly to the coalescence of glacial streams. In the discussion of the subject of elevating rocks, it was explained that the vertical and horizontal rotations, claimed to be inherent in the moving glacier, would gather and incorporate within itself, rocks and debris from the bottom and sides, which would be carried upward and inward, and sooner or later might appear on the back of the glacier. It seems to me if we could demonstrate this proposition, we could account for medial moraines otherwise than by the convergence of glacial streams or for medial moraines on glacial streams which have no branches. However, this subject is submitted with the others for discussion.

A paper before referred to says:

The neve or gathering ground of a glacier consists of an area of greater or less extent in a region of perpetual snow, where precipitation is generally excessive. It is a lake of compressed snow, or glacial ice, the source of the glacier.

If the neve is located between mountains and made up largely by avalanches, there will be a large proportion of rock intermingled with the ice; but if located in a plain, there will be none except at the bottom, where it may or may not intermingle with the ice, and become a part of the future glacier. This, of course, will depend greatly upon the character of the rock as to solidity and smoothness.

In its progress, the glacier disrupts ledges of rock, gathers rock

and debris, and by a peculiar movement elevates and incorporates them into its own mass; and whether the neve be formed in mountain or plain, or whether there be two or more converging glacial streams, or only a single one, the characteristic rocky backbone, technically called a medial moraine, in my opinion, will always be there. It is not necessarily the result of converging streams, but the result of the universal law which governs glacial movement and elevates rocks from valleys to mountain tops. This law was described in a paper read before this Society Oct. 30th, 1890, and illustrated by experiment on that occasion.

Another interesting subject relating to glacial geology presents itself, and one which the engineer should be quite competent to discuss, is the best method of tracing direction of glacial movement, whether by observing the striae on the bed rock or following transported material. The glacier is a granulated mass possessing certain elements of cohesion, and like a damp snowball, capable of being changed in form, and it moves as water does, in the direction of least resistance, whether east, west, north or south. The glacial stream which left the basin of Lake Michigan at South Chicago, the writer observed, moved southwest, west, northwest, and west again; all within a distance of less than thirty miles. Any person who has observed the indications of glacial movements as indicated by darts on geological maps, could not fail to see that the indications of the movement of the glacier somewhat resembles a weather map, and that the movement of the glacier from the lake at South Chicago, as described above, would compare well, for regularity, with the average as shown on maps, and when we consider how small a proportion of the whole unweathered glaciated area has been exposed to view and the great diversity shown in the observations taken, we are constrained to question the reliability of this method. The writer reached this conclusion early in his investigations, and has since relied, mainly, upon following transported material, which could be readily identified, not only as being more reliable, but very much more expeditious. For this disregard of established methods he has been severely criticised by some adherents to the old methods.

There are a few conspicuous geological formations which are readily recognized wherever found. Among these may be mentioned three Canadian conglomerates and the sandstones and copper of the Lake Superior region. Some of these have been transported and scattered over or along certain routes and not others, while others have been transported exclusively along other routes. These conglomerates, not one of which has been found on the Chicago Divide, have been traced from north of Lake Huron in Canada to Alton in Illinois, and by a route along which they are so abundantly scattered, that for a distance of seven hundred miles they form an almost unbroken chain; while the aggregate distance covered by this method of tracing is over two thousand miles. There is, however, one element of uncertainty in this method to which

your attention should be called; it is that of the scattering broadcast of these different formations, by icebergs at the close of the glacial epoch. This feature is presented for your consideration as detracting from the reliability of this method. And still another geological problem of great interest is the "Terminal Moraine." Until quite recently, the last seven years, or even later perhaps, any paper relating to glacial geology would be incomplete without conspicuous mention of the terminal moraine, now, however, there are quite a number of geologists who question the possibility of a terminal moraine. Among these may be mentioned Prof. Joseph Le Conte, of the University of Upper California, who has adopted the more modern expression, "attenuated border." Prof. Albert A. Wright, late of Oberlin and now of Yale, in a paper upon this subject published in the "American Geologist," began his paper by saying: "There is a snare in the words 'terminal moraine,'" as applied to the great ice sheet of the Glacial Epoch. The writer, in order to be plainly understood upon this subject, submits this proposition: The possibility of such a formation as a terminal moraine, as the expression has heretofore been used and understood, depends upon the possibility of constructing a dam of ooze, gravel, boulders and fragments of rock, in front of or upon the tongue or snout of a glacier, capable of withstanding the encroachments of a body of water having a head sufficient to either open a sub-glacial passage or otherwise surmount any elevation possible to be attained, under any glacial conditions, and thence to rush down the unprotected slope of a dam so constructed, the imaginary terminal moraine.

Following our investigations along the line of the glacial geology, we reach a point about the center of Sec. 7, where the character of the floor of the valley changes from bed rock, to the bed of an ancient lake, and whence it continues to Summit, a distance of 12 miles. This is what has been known as "the 12-mile level" of the Desplaines River. At the close of the glacial epoch, this was a glacial lake upon the crest of the divide between the lake basin and the valley of the Mississippi, and was in no sense a river, and in the absence of any other name, Mr. Ford and I have agreed to name it "Summit Lake." It had its own basin of about one hundred square miles in area; and two outlets through which it was tributary, alike, to Lake Michigan and the Mississippi; but after the completion of the silt dam across the valley of the Desplaines (Mud Lake) at Kedzie avenue, that stream, at normal stage, flowed through this lake and maintained an open zig-zag channel through it, while the rest of the lake was filled with silt and vegetable matter. In places this lake was deep, and others shallow, but whether deep or shallow, its bed was covered with boulders and fragments of rock, just as the glacier had left them thousands of years ago. During the progress of the work through this ancient lake bed, it has been like a panorama of the ice age, to the student of glacial geology. Each succeeding day has added interesting

features to this wonderful picture. In places where the boulder drift has been removed, masses of displaced rock were found of such a size as to raise the question as to which class they belonged, whether glacial drift or rock in place. In one instance, I understand, the displaced section was so large and so close to the line of rock in place, that the contractor was allowed rock price for removing it. In places in the drift sand so fine that a two or three-mile current would move it, could be seen either resting upon or supporting a mass of boulders of such size that a ten or twenty-mile current would not disturb them. In Section B—I think it was—a granite boulder weighing probably seven tons, was found lying by the side of a limestone boulder estimated to weigh thirty tons. In Section C, on one occasion when the steam shovel was making a cut, it encountered two cone-shaped deposits twenty feet in height and fifty feet apart. The shovel, as it moved along, cut through both, taking about one-half of each and showing a section of both from vertex to base. The material of which they were composed was of characteristic limestone boulders and this material was so absolutely alike as to suggest the idea that two chutes from the same hopper had delivered it at the same time. The space between these deposits was filled with sand and both above and below them (up stream and down) there was a deposit of the same material for a short distance. In Section D a granite boulder was found variously estimated from fifty to one hundred tons, and quite recently, in Section E, a boulder of red sandstone was found which was identified by Mr. Angus, an experienced stonecutter, as coming from the McArthur Quarry, on Nipigon Bay, Lake Superior. The writer has found several boulders of this material which have been compared and identified by Gen. McArthur and others as coming from that point. Mr. Ford has improved the opportunity of securing views all along the line. These views I consider the most interesting and valuable relating to glacial geology ever taken. I have taken the liberty of inviting Mr. Ford to attend this meeting and help me out with some of his views. It has been a disappointment to many visitors not to find glacial marked specimens of boulders more abundant along the channel. It is a fact that conspicuously marked specimens are, by comparison, scarce, but if you place any of the smooth limestone boulders under a powerful glass it will be discovered that not a single boulder of the millions you have seen has escaped the marking process. The explanation is that, the great mass of boulders is limestone, which rubs, but does not cut or scratch. Abundant glacial markings upon the floor of the valley, however, have fully compensated for this lack. Between Summit and the Chicago River the channel is cut along one side of the Mud Lake valley. In places along this line buried timber of unknown age has been found. The interesting feature, however, is the silt dam at Kedzie avenue, and through which the channel is cut. At this point the ancient valley of the Desplaines widens and the channel area so increased as

to allow the turbid water from that stream to drop its silt and form a dam to divert it to the Mississippi. This silt, which began to close this channel thousands of years ago, is as readily distinguished to-day both in character and color as when its deposition began at that remote period; and the line of demarkation between the glacial drift and the silt can be seen and determined now within a small fraction of an inch. The crest of this dam, which was about eleven feet above datum and effected the diversion of this stream to the Mississippi, was cut through by the Cook County Drainage Commission about 1851, when the floods of the Desplaines soon restored the old channel to its original depth, but not width; this, however, did not restore the Desplaines as a tributary to Lake Michigan for the reason that when the stream was diverted by the Kedzie avenue silt dam as before described it began to deposit silt along its margin across the Mud Lake valley, which soon developed into a barrier quite as effective, if not as formidable, as that at Kedzie avenue. This dam was cut when the Ogden-Wentworth ditch was excavated. I omitted to mention the fact that in passing through the ancient lake bed the remains of the mastodon, the buffalo and the antelope had been found in the peat, but no evidence of either man or animal has been found in the undisturbed glacial drift; although on one occasion a stone ax was found mixed with the drift at the bottom of a cut of over twenty feet.* The finder felt almost sure the long-looked-for evidence of pre-glacial man had been found, but upon more close investigation the ax itself furnished contrary proof of a most convincing character. The skilled and industrious artificer (for both of these he evidently was) found a glacial-planed boulder and utilized the planed side for one side of his ax, and not only finished the implement in a very workmanlike manner, but he polished the side and sharpened the edge to a degree seldom seen in these rude implements. The finder, one of the engineers at Lemont, and whose name I am sorry to say I cannot now recall, took much pains to save and present the implement to me. This ax, in my opinion, had fallen unobserved from the surface to the bottom of the cut, and become mixed with the drift where it was found. The writer during his investigations has not found a single trace of pre-glacial man, but he does not wish to be understood as offering his experience as proof that he did not exist. If man had existed here before the glacial epoch and had been possessed of implements, ornaments and pottery, unless preserved in a cave, it would have been impossible that either his remains or implements could have withstood the glacial ordeal.

Mr. Guthrie: Mr. Ford has been mining coal on the Drainage Canal to-day, and I will leave him to explain how he did it and to show some of the photographs he has taken of the geological formation.

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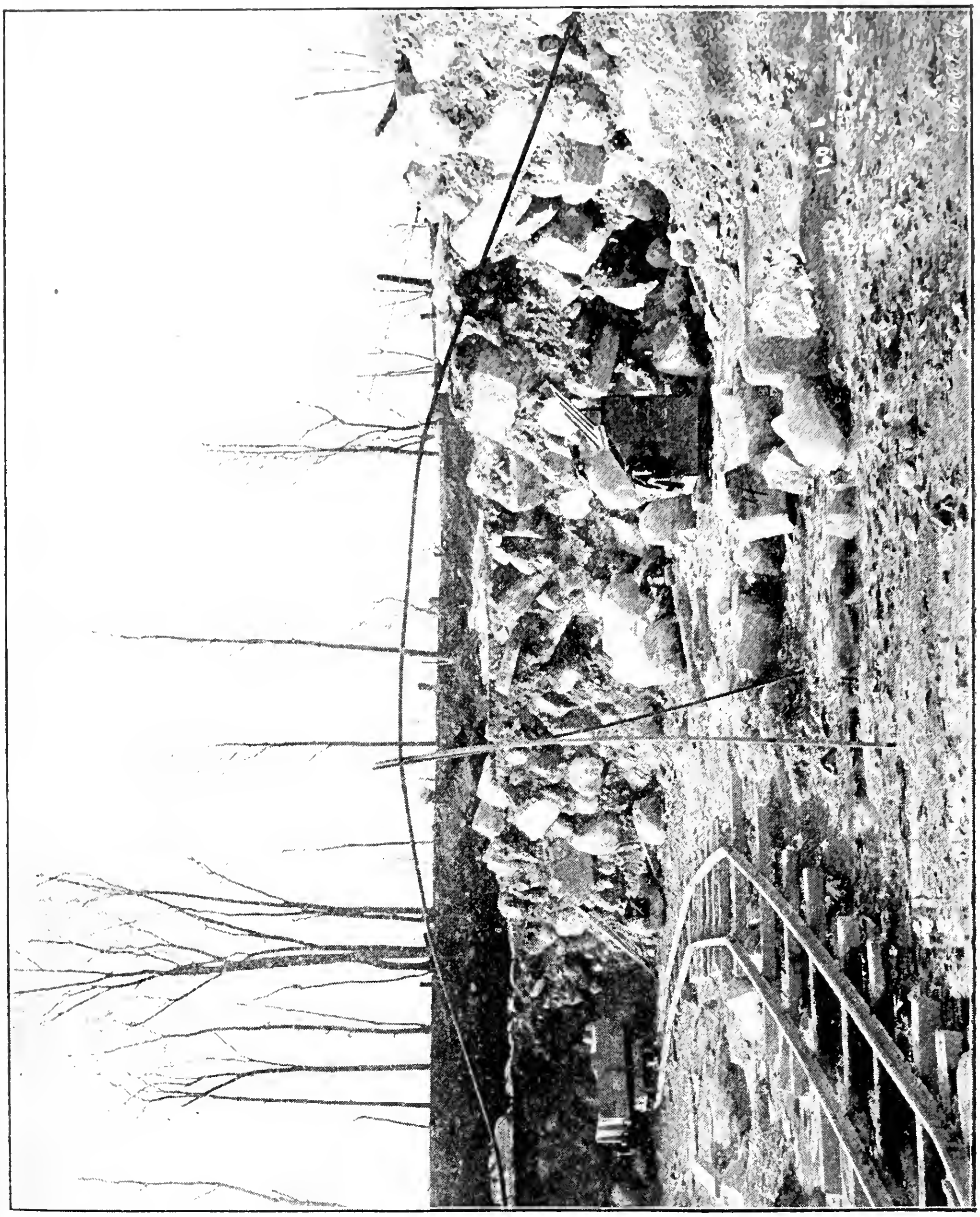
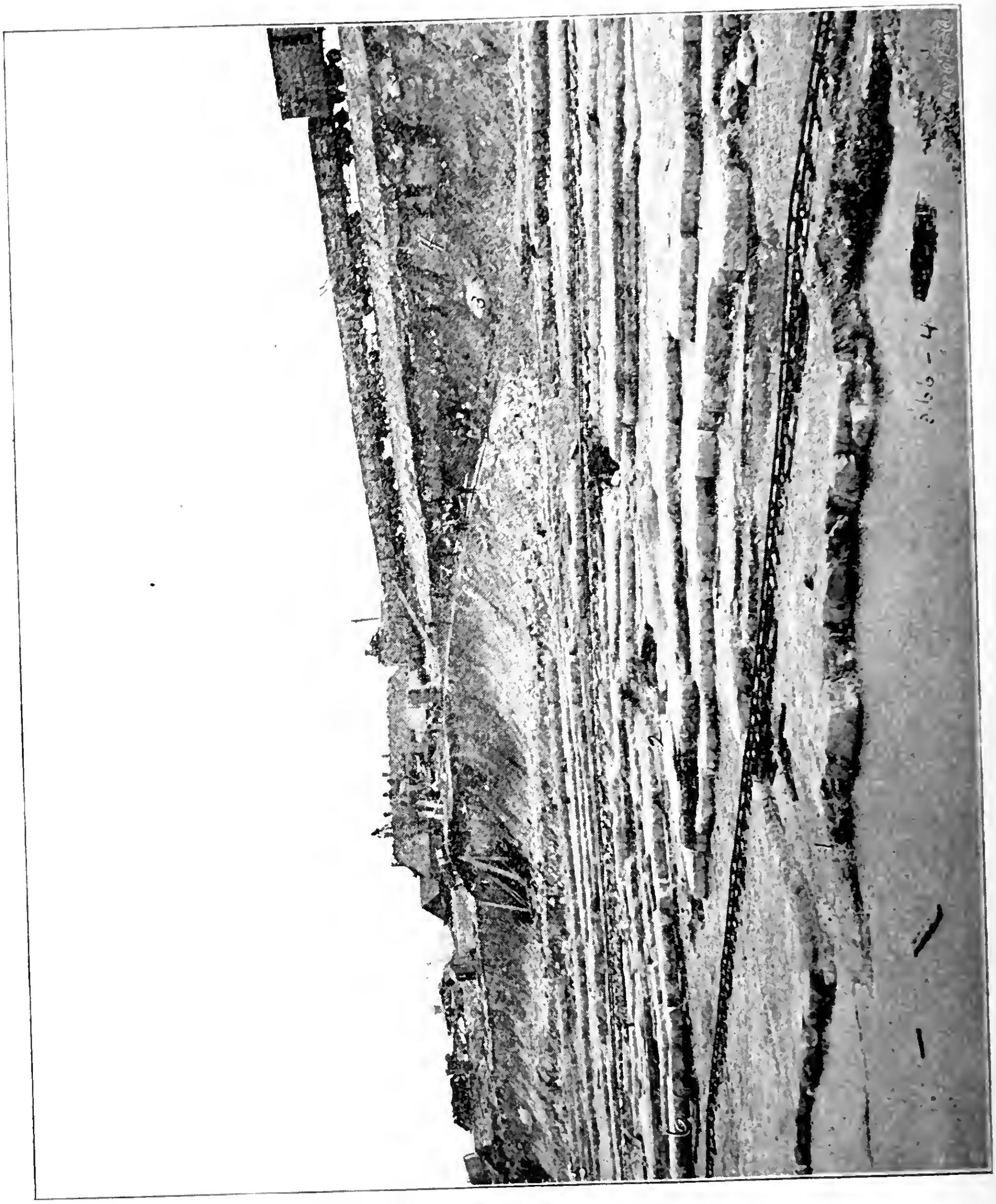
* Since this paper was read, a pair of antlers was found on Section B., in the deposits of peat, which there nearly reaches the bottom of the channel.



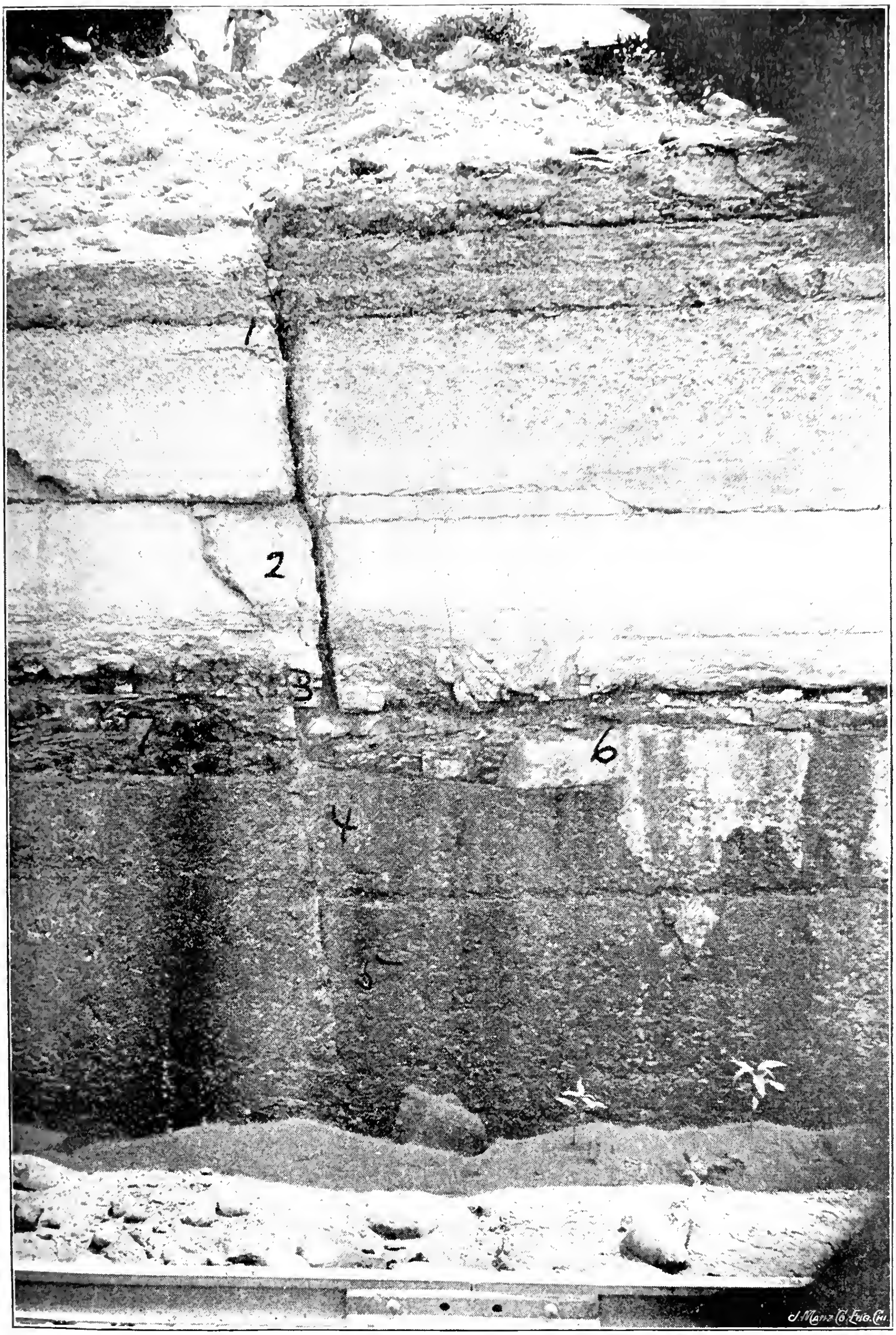
Copyright 1896, by Chas. H. Ford. FIG. 110.

View of the drift on Sec. 6, at the top is the peat bed (1) which formed in the bottom of Lake Summit. Underneath it is the drift (2), much of which has evidently been derived from the immediate vicinity. The position of the limestone slabs pointing upward in the direction of the ice current, sheds some light upon the movement of the englacial drift. Scattered through this limestone drift are boulders of many sizes and varieties that have come from the regions far north. Under the drift is the native limestone rock, rounded (3) and crushed into sections (4) by the action of the ice mass.



Copyright 1896, by Chas. H. Ford. FIG. 111.

One side of the bed of the glacial stream, slightly diagonal to the drainage channel on Sec. 4. The total distance is about 1,100 feet and two thick strata are above and beyond, at the left (5). The strata show surface indications of glacial scoring and smoothing, and the upper layers are considerably displaced. The course of the stream is from left to right, parallel with the edges of the broken strata. At 4 is a bed of sand overlying gravel and in turn overlaid with boulders, one of which (3) six feet in length, has fallen from its position at the top of the glacial drift. From 6 to 2 is a cave in the rock cut out by the tearing movement of the ice stream.



Copyright 1896, by Chas. H. Ford. FIG. 112.

Sectional view of rock wall on Section 4 not far from the eastern end of Fig. 2. The upper strata (1, 2, 3) are shoved down stream, and the contiguous surfaces (6, 7) are crumpled by the pressure and sliding. The crack (1, 2, 4, 5), which is diagonal in two planes, measures at 3, the extent of the movement, which is four inches.

Copyright 1896, by Chas. H. Ford. FIG. 113.

Surface stratum of the bed rock which has been scored, smoothed and shoved upon the underlying stratum. The spaces between the fragments (1, 2, 5, 6, 7) indicate the beginning of the process of separation preparatory to the rock being mixed into the englacial drift. The sides of the fragments (8) showed by their smoothness the evidence of the rubbing against each other. In the background (3) is seen the western end of Fig. 2. The 3,000 feet from Fig. 3 westward is one of the richest, geologically, on the canal, 9 indicates the probable starting point of the movement of this particular section of the stratum.

REMARKS BY MR. CHAS. H. FORD.

Mr. Chairman and gentlemen: I do not know that there is much explanation. No doubt you have all heard of the clay pockets down in the lower portion of the Drainage Canal, and to show how hard it is to know everything all at once, I may say that my first view of those clay pockets was yesterday. My work along the Drainage

Canal, while I think I have given considerable time to it, has been almost entirely in the portion east of Lemont, and yesterday I was fortunate enough, in investigating the first clay pocket I had seen, to find scattered through the clay, which is evidently glacial clay, a large amount of coal, and here are some specimens of it. The quality seems to vary, some being much purer than others. Scat-

Copyright 1896, by Chas. H. Ford. FIG. 114.

Sectional view of channel wall to show the shearing of strata in consequence of the shoving force of the ice movement.

The lowest strata (1, 2) are bed rock. The next two or three (3,4) are somewhat displaced and broken by the movement (especially near 10); the thinner strata above (5, 6, 8, 9, 10) have been shoved some distance, and in the process has been produced the shearing which is shown in the middle of the view, at 7, where 6, 10, at one time continuous with 5, have been broken off and shoved over it. Above is characteristic glacial drift. Taken on Sec. 1, at Willow Springs, where a distance of 3,000 feet from the beginning of the real "rock cut" supplies some of the most remarkable of the geological views found on the canal.

tered through this clay there is seen a large quantity of small pebbles which are different from anything I have found anywhere else in glacial drift. These seem to be small soft greenish pebbles; we find some boulders of this same material, perhaps a foot in diameter, which could be cut with a knife. Mr. Higginson, I think it was, has suggested to me that it probably contained a small amount of an ore of nickel, which furnished the color. The color is very similar to that which is found between the layers of much of the limestone that we find. Perhaps you have noticed that where the layers come together there is often a deposit of a greenish substance. I have been puzzled myself to know what it was, but that information, I suppose, can be depended upon, that it is one of the ores of nickel.

In these pockets we find a great many pieces of rock, just such as are found in the glacial drift. Some of the rocks are rounded, some of them are angular. Mr. Christie and I yesterday on our trip found jasper and granite among the specimens that we picked out with the coal, and the limestone is there in considerable amounts.

One thing in reference to the pockets I noticed very carefully. We have had some photographs taken of that—there seems to have been in every case water action where the wall of the pocket is laid bare. There is either the action of water in dissolving, as in a limestone cave, or there is the action of water using a stone for an implement in wearing out, and it is my conviction that a large number of those clay pockets are pot holes which the glacier either found or made in its course, and some, perhaps, were caves, uncovered as it tore out the rock and then filled up with the glacial clay. Some of these holes are still found entirely covered, so that part, at least, were caves. Of course a cave might become a pot-hole.

I may say in passing that I cannot understand how Mr. Guthrie should have used what seems to be so ridiculously low a figure as five hundred million cubic yards of stone eroded from this valley. I have not figured on the matter, but remembering that the excavation from the Drainage Canal is forty million cubic yards, I cannot see how it is possible to put the figure at anything like such an amount.

I may say, in general, in reference to the pictures, that they have been taken for the most part along Sections 1, 4 and 5, a few on Section 6. They represent the movement, very characteristic there, in harmony with the evidences and manifestations that we have found in other places, but they represent there the movement of the glacial stream, which seems at some time or other to have stopped with comparative suddenness, and when it stopped it appears to have melted down in that place and to have deposited the drift as a seal upon the material or the condition it had left behind it. That seal in that limestone drift is a hermetical seal, and when we uncover the surface of the rock we find just exactly what the glacier left. I think we may compare it to the conditions we find in Herculaneum and Pompeii. I have not been there, but

as far as my information goes there are found, on opposite sides of the counter, people transacting ordinary business, or in other positions going about their regular work, buried as they were. So here, where the glacier was doing one thing in one place and at other places still other things, we find all those things were preserved by the sudden stoppage and the dropping of this material in that way. Situated as this material was, back of the rocky dam at Lemont, that is, on the up-stream side, where the sub-glacial water could not wash it all out, it left room for the peat beds which Mr. Guthrie spoke of, which are over by the drift in that part of the valley.

Situated in that way, the lower portions (I do not say the upper part or the whole), the lower portions of the drift which were left by the ice remained intact, and we have it photographed, and here is the documentary evidence which can be handed down to future generations.

The photographs of the foregoing views were taken by John F. Geiger, Lemont, Ill. Negatives in possession of Chas. H. Ford, by whose permission they are here reproduced. These views are from a set of 100, entitled "Foot-Prints of the Ice King," taken for Mr. Ford, and under his direction, in the region of the Drainage Canal.

XI.

NOTES ON COAL.

By Chas. F. White, M. W. S. E.

Read August 19, 1896.

The market of Chicago for steam coals is supplied from many coal mining districts, with a number of grades of coal, of a variety of qualities, and at various prices. Coal comes from Pennsylvania, West Virginia, Kentucky, Ohio, Indiana and Illinois, and from all but the most remote districts it comes in the several forms of mine run, lump, egg, nut, and screenings.

When it is remembered that each of these varieties will vary in steam producing results with the conditions under which it is burned it will not appear strange that there exists a great diversity of opinion as to the coal it is best to use and that there are frequent changes from one kind to another by the same purchaser.

Because the results obtained under one set of conditions will not be attained under other conditions it has not seemed best to specify quantitatively the results found in testing various coals. I have confined myself to some data and observations on the water measurements in such work, the variations found in repeated tests, and some notes on the relations of high grade and low grade coals.

Most of the tests have been made in one building on a return tubular boiler 18 feet long, 5 feet in diameter, with 46 tubes 4 inches in diameter. The furnace serving this boiler is of external retort shaped construction. The grate area is 20 square feet. The boiler heating surface area is 1,020 square feet.

Part of the tests have been made with water tube boilers of 1,875 square feet of heating and 33 square feet of grate area each, served by automatic stokers under retort shaped arches and supplied with nut coal and screenings.

Prevention of smoke was a primary object in the installation of these brick-arched furnaces. Thus far the use of small coal with the automatic stokers gives a unit of work for about 14 per cent less fuel cost than that entailed by the use of larger sized coal in the hand fired furnaces first mentioned. No tests have been of less than ten hours' duration.

As it has been necessary for me to make tests without assistance the apparatus used has been made as simple as possible.

The usual methods are employed to determine the weights of fuel, the pressures and temperatures. To determine the weights of water a hot water meter is used.

As the advisability of using a meter for such purposes is often questioned, the details of using one, the checks employed, and the results obtained may be useful. It may be stated that the only reasons for using a meter are its great convenience and saving of labor. So far as I know all meters have an error—that is, they discharge a quantity of water different from the amount registered on

the dials. Usually the actual discharge is greater than that registered, and when this is the case the error, stated in percentage of the registration, will be the less the greater the rate of flow through the meter. Therefore, in calibrating a meter it is important that the rate of flow during the calibration shall be the same as the rate during the test period.

The error of a meter will also change, due to the wear of the parts, and the actual error during any period will be a compound of these two factors.

A meter should be calibrated at least once for each day's use. For this purpose I have found the apparatus shown in figure 1 very convenient to use and capable of yielding quite uniform results in successive calibration measurements.

The arrangement is based on the idea that if the flow through the meter is kept at a certain rate per minute there will be no need to take account of the pressure, since a given difference between the pressures on the inlet and discharge sides of the meter will cause a corresponding speed of flow through the meter.

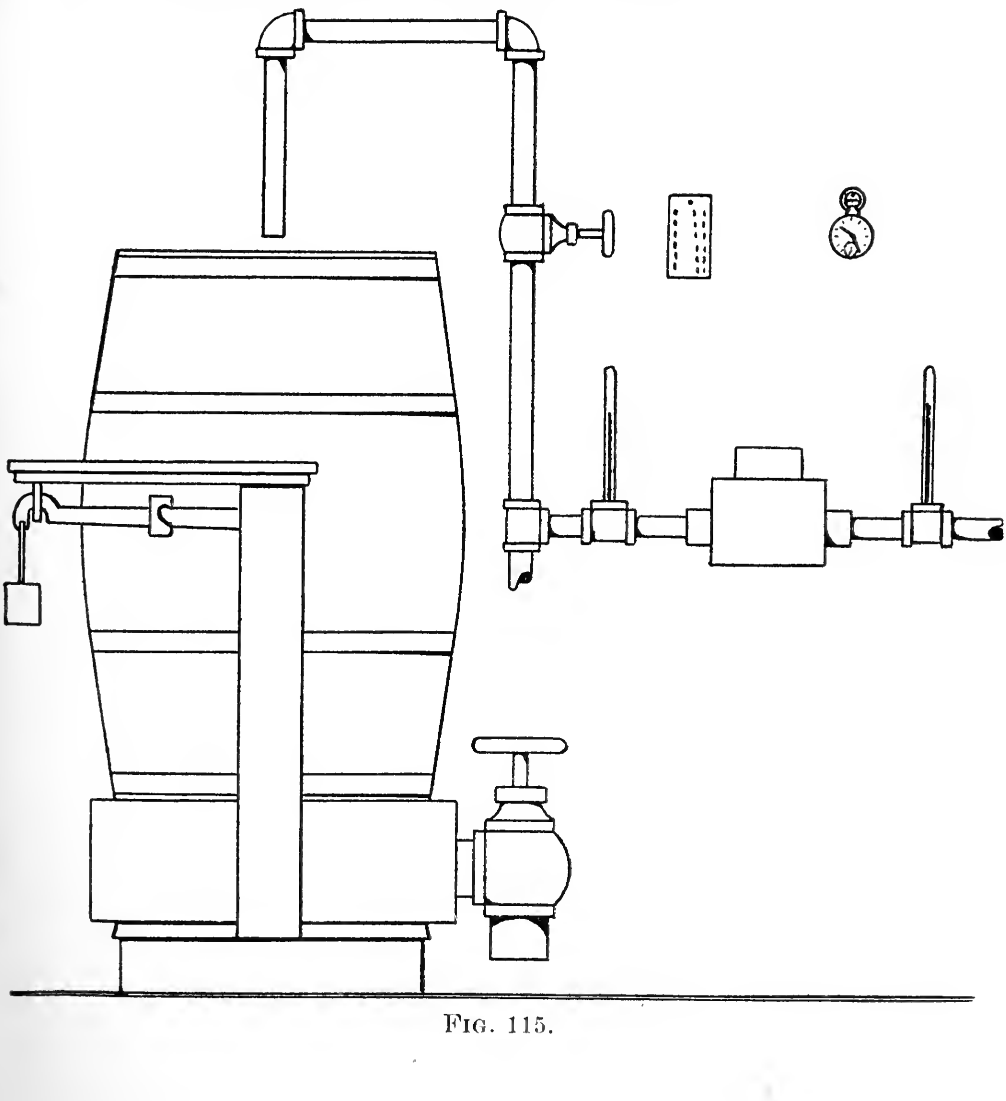


FIG. 115.

In the figure (115) the meter is located so as to bring the dial into easy view. Thermometers are placed in the inlet and in the discharge pipes close to the meter. The inlet valve is kept fully open. The flow is regulated by the valve in the discharge pipe. The water is weighed in a barrel holding about 420 pounds of water at 200 degrees Fahrenheit. The barrel is mounted on a 600 pound platform scale. The weighed water is discharged into a sewer basin through a 3 inch valve. The upper head is left in the barrel as a cover, with a $2\frac{1}{2}$ inch hole to admit the water. The barrel and fixtures are balanced by a special weight, making it necessary to take one reading of weight only. A watch is hung in direct view, also a card showing the time of discharge for each cubic foot of flow.

The arrangement of the record sheet is shown filled out in table XXXIII and is a copy of a page in my meter test note book. It will be seen that 30 cubic feet of water, weighed six feet at a time, constitute a calibration.

TABLE XXXIII.

Registration.	Time.	Temperature.	Weight.	Error.
016200.0	11-37-0	194		
		196		
		197		
		197		
		197		
6.0	44-43	197	373.60	
	47-0	194		Rate=47.7
		197		
		198		
		198		30 feet at 195.2
		200		= @ 60.20 each
12.0	54-41	200	372.10	1806.
	57-0	195		
		195		
		194		1862.45
		193		1806.
		193		
18.0	12-04-16	192	372.25	56.45
	6-0	189		
		192		
		193		$\frac{56.45}{18.06}$ = 03125
		193		
		194		
24.0	13-32	195	373.	
	16-0	194		Slip=$3\frac{1}{8}$%
		196		
		196		
		196		
		196		
016230.0	23-31	195	371.50	
30	37-43	30 | 5856 195.2	1862.45	

In calibrating, the initial reading is decided on and entered beforehand. Water is then run through the meter into the barrel and stopped by a quick closure of the discharge valve exactly as the pointer reaches the index. The barrel is then drained and balanced. The time for starting is now entered on the record and the valve opened as the second hand indicates the time. The rate of flow can be very nearly adjusted during the first half foot of flow and corrected thereafter as each foot is recorded by reference to the card, which shows the normal time. The reading of each thermometer is taken at the middle of each foot flow and the mean reading entered. The usual difference varies, from 4 degrees the first foot to nothing the third foot when the meter has been idle about three minutes, with the water at 200 degrees in an atmosphere of about 80 degrees. At the instant the dial registers the sixth foot the valve is closed and the time noted. The barrel is then weighed, emptied and balanced, completing the cycle.

The usual interval for weighing, discharging and balancing is from two to two and a half minutes.

By this method a difference in closing the discharge valve the first time and the last time is the only one affecting the accuracy of the result. The sample record sheet shows how nearly the individual barrels may agree in weight.

Table XXXIV gives the condensed data of twenty successive calibrations of one meter, no adjustment having been made during the

TABLE XXXIV.

Rate of Flow in Cubic Feet per Hour as Registered.	Excess of Flow in Percentage of the Registration.
60.	3.41
48.25	3.87
47.40	5.12
57.80	5.56
55.	6.36
68.50	6.33
74.22	7.31
59.	9.04
50.	11.11
59.	10.15
52.30	11.76
88.	9.40
49.60	12.14
65.70	11.20
49	13.62
57.50	13.39
36.	18.83
44.	17.14
37.60	18.23
54.	15.78

series, which embraced a total flow of about 11,000 cubic feet. Nearly similar results have been reached with other meters. Examination of the table will show an increase of error at each succeeding calibration for a given rate of flow. A very interesting record would result from plotting the error at a fixed series of rates of flow and at equal intervals of registration. It is quite possible, however, that the mechanical differences in individual meters would render such a tabulation of little practical value. The table, however, emphasizes sufficiently the necessity of frequent calibration where accuracy is expected in the use of a water meter.

RESULTS OF PARALLEL TESTS.

Having outlined the methods used, it will be interesting to see how nearly uniform results have been obtained where successive tests have been made with coals supposedly the same. I should say here that no special effort has been made to have the coals burned at exactly the same rate per hour in these pairs of tests. Had it been done more uniform results would probably have been attained. Table XXXV gives the evaporation of water per pound of coal from and at 212 degrees and the differences for each pair of tests.

In these sixteen pairs of tests the variation is from nearly nothing to 4½ per cent and averages 1 8-10 per cent. These variations

TABLE XXXV.

	Evaporation.	Difference.		Evaporation.	Difference.
a	7.67 7.56	.11	i	9.20 9.16	.04
b	7.47 7.45	.02	j	8.56 8.34	.22
c	7.74 7.67	.07	k	9.12 8.93	.19
d	9.84 9.51	.33	l	9.59 9.37	.22
e	7.62 7.57	.05	m	6.03 5.96	.07
f	7.40 7.28	.12	n	5.19 4.96	.23
g	7.10 7.03	.07	o	6.44 6.37	.07
h	5.83 5.82	.01	p	7.91 7.57	.34

in results are the sums of all errors in observations with any real differences in the fuel and differences in handling.

Assuming the evaporative value of the various coals under the working conditions to have been determined with reasonable accuracy, a point to be fully considered is the freedom with which the coal burns. The coal must be such that enough of it can be burned in a given time to produce the maximum quantity of steam required for the service. Coals vary in this regard very considerably. Some are found of high evaporative powers, which are badly handicapped by a slow burning quality which prevents the forcing of a fire to meet a call for steam which may last but a small part of the time.

This free burning quality is a valuable one and gives to some coals of moderate evaporative power an advantage for many steam users and one which tells upon the price obtainable in the market. Another important consideration is the character of the refuse. In furnaces of the fire brick retort type the temperature is relatively high. Coals with a refuse readily melting into a thin slag are unfit to use in such unless at a slow rate of combustion. The melted ash forms a sheet clinker next to the grates in one or two hours, the effect of which is to cut off the air flow and consequently reduce to a great extent the quantity of steam which can be made. In the presence of such coals shaking grates are of but little use, simply lifting the entire mass of fuel in the furnace without breaking up the clinker sheet. Such coals are best used in the ordinary flat grate furnace, in which the temperature is lower and which permits quick cleaning of the fire.

HIGH GRADE OR LOW GRADE COAL.

It is not uncommon to hear steam users say that the cheapest coal they can get gives them the smallest fuel bills. It is equally common to hear men working steam plants say there is no profit in using cheap coal. In the issue of Electrical Engineering for April, 1896, page 256, a writer on fuel quotes himself in a previous issue as saying: "The cheaper the coal the cheaper the steam, so long as the interest on the investment to secure capacity did not more than equal the saving made." He goes on to say: "I now feel that this rule can be extended, and after several hundred boiler trials since then have found that the price of the steam varies with the price of the coal, so long as the coal is burned intelligently." That this view is a correct one seems evident, because value to a purchaser is a function of price and performance. If coal of high grade and coal of lower grade be offered a purchaser at prices such as to make the value or cost to him equal he will certainly choose the higher grade, and it follows that low grade coals must be offered at prices which shall advantage the buyer in order to be sold at all, or the qualities of a strong coal, fitting it to overcome adverse conditions, put a pre-

mium upon its price, making it relatively expensive to burn where the conditions do not preclude the use of a poor coal.

Where several coals of different exaporative values and different prices are to be compared a convenient unit of comparison is the cost of evaporating one ton (2,000 pounds) of water, since this can be had by simple division of the price in cents by the evaporation in pounds of water per pound of coal from and at 212 degrees, the result being the fuel cost in cents.

In table XXXVI there is given for three coals the price per ton, the evaporation and the fuel cost of a unit's work obtained as just described. The table is arranged to show the difference between each kind in price and the difference in fuel cost and also shows the same differences expressed in percentage of the lesser. The table XXXVI is expressive of the force in the modifying clause quoted above: "So long as the coal is burned intelligently;" for it will be noted that the differences in price are from four to five times as great as the difference in cost per unit of work; expressing the fact that the particular furnace used is not one well adapted to low grade fuel, although with it the low grade fuels showed in each case a somewhat lower cost.

TABLE XXXVI.

Coal.	Price.	Evaporation.	Cost.
a	$3.325	9.	$36.94
b	2.695	7.6	35.46
Difference	.63		1.48
Per cent	.234		.041
a	3.325	9.	36.94
c	2 455	7.1	34.57
Difference	.87		2.37
Per cent	.35		.068
b	2.695	7.6	35.46
c	2.455	7.1	34.57
Difference	.24		.89
Per cent	.095		.025

STANDPOINTS OF BOILER OWNER AND FIREMAN.

The saving effected by the use of a low grade coal goes to the boiler owner. The expense of extra labor is laid upon the fireman. Or the use of a high grade coal advantages the fireman at the ex-

pense of the owner. A change of fuel which may involve but little difference in evaporative cost may easily increase a fireman's work very much.

A coal, say 10 per cent poorer than another, may by the quantity and character of the ash more than double the severe parts of a fireman's work which are connected with cleaning fires and disposing of the refuse with the necessity of maintaining steam pressure at such times.

These facts form the basis of the differences entertained on the question of high-grade fuels as against those of lower grade and lesser price.

DISCUSSION.

Mr. R. E. Orr: I would like to ask Mr. White if he has ever examined the Pocahontas or New River coal?

Mr. White: No, sir; I have not. The furnace with which nearly all the buildings I have anything to do are equipped is hardly adapted to burning either Pocahontas or New River coal. They coke strongly and in the furnaces which we have we are obliged to carry very quick fire, and these coals are not used owing to their high coking quality.

Mr. Orr: Pocahontas coal does not coke up after it is broken.

Mr. White: That is a difficult matter in a furnace carrying a thick fire. Fires in many of these smoke preventing furnaces vary from eight to fifteen inches thick, and a bed of fuel as thick as that is quite difficult to manipulate. Where coal is put in on so thick a fire it is almost impossible to break it up. If a large mass is put in it cokes and actually chokes the furnace with the swell due to the coking. A limited amount of coking does no harm, but if the swelling at coking is as heavy as it is with the New River coal it involves considerable difficulty in using.

Mr. Orr. The Pocahontas coal is very low in ash.

Mr. White: Yes, and it has a high evaporative power. There is a considerable difference in ash according as the coal is treated. I recall from memory a case where a certain Indiana bituminous coal was used in our automatic stokers and a boiler rated at 250 horse power was run at about 175. At that rate nothing could be more satisfactory than the operation of that coal. The refuse worked down through the grates of the automatic stokers perfectly. It remained in the state that firemen call dry ash. It did not stick. In a successive test, when I wished to see the operation of the coal with the boiler carried to its full capacity, almost the entire contents of the furnace fused at the temperature which was then raised. The ash melted and could be taken out of the furnace almost exactly as glass would be taken out of a glass furnace. When broken it was of a very glass-like consistency and that coal was the very same

coal; there was probably no difference except in the rate at which it was attempted to burn it.

Mr. Orr. What is the reason you carry such heavy fire?

Mr. White: The furnace which is used involves them. The grates are at an angle of about 22½ degrees and then there is a flat section in the center. These sides are stationary grates and the center part is a shaking grate. The coal is filled in through a pocket on either side, fed by hand, so that it falls in general in an irregular mass across from the mouth of the pocket. The heat of the arch is constantly radiated down on the top of the fire, and is one of the material aids in preventing the smoke. It can be seen that with a furnace having grates of the shape described the difficulties of manipulating or cleaning a fire are much multiplied.

A Member: How are the grates cleaned?

Mr. White: Through a door directly in front.

A Member: Does the Great Northern Hotel have a furnace like that?

Mr. White: I do not know.

A Member: I would like to ask whether that per cent of slip of the meter means per cent of the registration of the meter?

Mr. White: Yes.

Mr. Dougherty: How long had that meter been used?

Mr. White: About twenty days.

Mr. Forbes: It would seem that it would be rather an unreliable instrument for constant use if it would vary that much in less than a month.

Mr. White: That is one of the points which I wished to bring out in describing this way of testing a meter. It emphasizes the point that it is unsafe to use a meter for such a purpose unless you calibrate it frequently. The meter should be calibrated as often as once a day.

Mr. Liljencrantz: According to what you have said, Mr. White, I should think that the meters used by the water department of the city would be useless after using a short time. Of course the correct measurement is not so important.

Mr. White: That is really the point. If the loss inflicted fell on the consumers I suppose we should hear from them, but as the loss falls on the city nothing is said about it.

Mr. Kellogg: Mr. White, can you give us really any percentage on the intelligence of the fireman? Isn't that one of the greatest factors we have to calculate on?

Mr. White: I cannot give any percentage on the intelligence of the fireman. I have no data on that point.

Mr. Kellogg: It is a great factor, however.

Mr. White: It is a factor; how great a factor I do not know. It is my own judgment that the temper of the man counts for more than his intelligence, as that word is sometimes used. It is the tem-

per of doing faithfully what he has to do with a fair amount of intelligence.

Mr. Kellogg: Experience will show that the personal equation of firemen has much to do with the cost of the coal.

Mr. White: It certainly has an effect.

Mr. Forbes: So that really a consumer of coal cannot determine what the cost is unless he has an expert to examine it?

Mr. White: He can know what his monthly costs are by his bills, but the ordinary purchaser of coal has hardly any means of knowing which coal is best, except as he judges by the monthly bills, and as the last resort that is what you have to judge by.

A Member: Can a fireman, changed from one coal to another, get the best results? Is not different treatment necessary to secure them?

Mr. White: Yes, particularly if the coals are of a widely different character. You frequently get coals not very dissimilar in required treatment and in such cases probably the fireman would do nearly as well after a couple of hours as he would after a week. In so far as these tests have been concerned firemen have always had the coal a day or two in advance of the time the test was made, enough so that they could become fairly familiar with it.

XII.

STREET PAVEMENTS IN CHICAGO.

By Cicero D. Hill, M. W. S. E.

Read September 2, 1896.

Mr. President and Gentlemen of the Western Society of Engineers:

There are not many of you who are professionally interested in the subject of street pavement, but a good many of you, I hope, are owners of real estate, and in that way take a financial interest in the subject, and even those who do not own real estate are apt to be consulted informally by friends and neighbors as to what pavement is the best and how it should be laid. The general public is indisposed to pay for engineering advice, but quite readily and indiscriminately accepts it when it is gratuitously offered, no matter how little experience the adviser may have had in this particular line. This being the case, I consider it the duty of any engineer who is informed on the subject, to advise his fellow citizens, who are interested in any public undertaking, as to the best methods to pursue, and if it is not possible to have an engineer who makes a specialty of that particular branch of the profession retained at a fair compensation, then in the interest of the common good such advice should be given freely. It would be beyond my power to write a paper on street pavements that would be so abstruse and technical as to be intelligible only to the profession; therefore it is my purpose to state the general principles of road building in such a manner that any one can get a fair idea of what kind of a pavement should be adopted for any particular case, and how the work should be done. I will not go into the historical aspect of the case nor deal with the literature on the subject, as all that is available to you, and it would gain nothing by repetition here, but I will give my own views and opinions based on my experience in this vicinity.

AS TO KIND OF PAVEMENT.

In the first place, there is no pavement that is perfect or that approaches perfection, and there never will be such. There are too many conditions and requirements to be met, and the pavement that comes the nearest to meeting one set of requirements will be the farthest away from some other requirement. These conditions and requirements vary greatly in different localities and therefore the pavement that is most suitable for one locality is utterly unfit for another. No man who is at all posted on the subject and who is not financially interested in some particular pavement will advocate the use of any one kind of pavement under all circumstances and conditions. In deciding upon the best pave-

ment for any particular street we must take into consideration the character of the soil, the drainage, the gradient of the street, the character and amount of traffic, the taste and habits of the residents, the condition and value of the property along the street and the ability of the owners to pay for a more or less expensive improvement. The question of cleanliness, noise, durability, slipperiness, ease of traction, first cost and cost of maintenance must be considered. In a first-class residence street cleanliness and quiet are the considerations of most importance; in a manufacturing district, where the traffic is heavy, durability and ease of traction are to be first considered; in other residence streets where the property owners cannot afford an expensive pavement, the important consideration is a low cost. It would be impossible in the limits of this paper to take up all the conditions and requirements of a pavement and see how well the different kinds meet them, but we will briefly consider the various pavements to be found in Chicago and note the conditions under which each of them is preferable to any others.

GRANITE BLOCK PAVEMENT.

This pavement should be laid on a solid foundation either of concrete or crushed stone that has been compacted by a heavy steam roller until it is unyielding; the blocks should be of very tough stone that will not break under heavy ramming nor chip at the corners under the action of the horses' shoes. The blocks should be made more regular in size than is generally the case; should have straight sides and ends and be laid as closely together as possible. It is impossible to make the joints so tight that the horses will not get a good foot-hold. The greatest objection to this pavement is the noise caused by the traffic, and this noise would be greatly reduced if the blocks were more carefully made and laid. In the city specifications preference is expressed for stone that will wear roughly and will not take a polish. In my opinion this is unwise, as such stone will wear away at the edges and the pavement will consist of rows of rounded stones, with large joints like a cobble stone pavement. An example of such a pavement is the Medina stone block pavement surrounding the old postoffice. The slipperiness of the individual blocks is of little consequence inasmuch as the horses' shoes will catch in the joints. The slipperiness of granite block pavement is generally overestimated, many of the cases of horses falling are due to street car tracks rather than to the blocks themselves. The great merit of this pavement is its durability, for the blocks are practically indestructible. There are some streets in Chicago on which no other pavement would last ten years, and it would seem to be economy to pay $3 a square yard for this pavement rather than $1 or $2 a square yard for a pavement that would have to be renewed in five or ten years. On

the other hand, if we consider the wear and tear on horseflesh, vehicles, and most of all, the nerves of the office men of Chicago, we may doubt the economy of this pavement. As to other requirements of a pavement it does not differ much from brick, asphalt or wood.

It is a little more difficult to clean, but gives a better foot-hold for horses drawing heavy loads than brick or asphalt, while the contrary is true to a slight degree in comparison with wood. It is an unpleasant pavement to drive over in a light carriage, but in a street that is to be used almost exclusively for heavy traffic these considerations are of little importance.

ASPHALT PAVEMENT.

Sheet asphalt is claimed by its advocates to be the ideal pavement. It is claimed to be very cleanly and sanitary, very durable, hence truly economical, although the first cost is high. In some of the eastern cities it is used extensively on the best residence streets, and in New York City it is used on many of the heavy traffic streets, in some cases being laid on top of the granite block pavement, and has successfully stood many years of heavy traffic. I am free to confess that I don't know much about laying an asphalt pavement, but I am forced to believe that pavements that have been so durable in Washington and New York City differ in some essential manner from the asphalt pavements that have been laid in Chicago. So far as my observation goes the asphalt pavements in this city have not been durable. Although they are kept in repair by the contractor for a period of five years, they soon get into bad condition after that period has elapsed. Until recently this pavement has been confined to our residence streets and boulevards, but a notable exception was made last year when West Madison street was paved, and this bids fair to form a precedent for more asphalt on similar streets. The pavement on this street, so far as I am able to judge, was built in a very substantial manner and was finished about eight months ago, and although the traffic is much less than it is on the down-town streets, a well-defined rut is beginning to show about five feet from the car track. The chief merits of this pavement are ease of cleaning it and ease of traction due to its smooth surface.

Its chief faults are high cost and slipperiness. Where there is a good deal of fast driving the clicking of the horses' shoes on the hard surface is very annoying to nervous residents. The promoters of this pavement say but little about the ease of traction, but this is its chief merit in the eyes of teamsters. A horse can draw a heavier load over this pavement than any other, and where there is a long stretch of it a teamster will frequently take advantage of it and use the street in preference to others. As to cleanliness it

is not only easy to clean but it is essential that it be kept clean, for the slightest wind will blow the dust and filth about. On a hot summer's day the water from a sprinkling cart will evaporate in a few minutes, and the only way to keep the dirt from blowing about is to remove it from the street. Again, where the dirt is left on the pavement and kept wet the asphalt is very apt to rot. It is for this reason that asphalt streets are generally provided with gutters paved with other material; for this purpose the concrete combined curb and gutter is admirable and is frequently used. In my opinion sheet asphalt, as it is constructed in Chicago, should not be laid on boulevards where there is a great deal of pleasure driving, and it should not be laid on residence streets where the property is worth but $50 or $60 a front foot and where the property owners are trying to pay off their mortgages. I believe the proper place for this pavement is on streets that have been built up with handsome residences, where the traffic is comparatively light and where the property owners are public-spirited enough to unite in an association for the purpose of keeping the street absolutely clean and are willing to pay for the slight repairs that are needed from time to time.

BRICK PAVEMENT.

Brick pavement in Chicago is a new thing. It is about five years since the first street in this city was paved with brick, and until last year there were less than three miles of this pavement. The important question with this pavement is its durability. In the smaller cities and towns of this and neighboring states there have been a few streets paved with brick for several years, and the pavement has shown very little effect of the traffic. It has been inferred from this experience that the life of a brick pavement is from fifteen to twenty years. However, it is impossible to judge from such data how long a brick pavement would last in one of our down-town streets. One of the brick manufacturers of this state had sufficient confidence in his own material to put down an experimental piece of pavement on Lasalle street, between Madison and Washington streets, and after exposure to heavy traffic for a year and a half it is still there. It is only fair to say that in one year this pavement has had harder usage than it would have in ten years in a small town or on a quiet residence street in this city. Still I do not believe that it will remain in good condition for many years, and I doubt if it lasts any longer than a good cedar block pavement would. One of the best tests of brick pavement laid in this city is that laid in front of the freight houses of the C., B. & Q. Ry. I am not certain how long this has been down, I think three or four years, and it has been subjected to very heavy and continuous traffic. The pavement is generally in fair condition.

except where the horses stand in front of each door. It is the custom of the teamsters to back their trucks up to the doors of the freight house and swing the horses around out of the way of passing teams in such a manner that the horses always stand in the same place. The result is that the stamping of the horses has made holes in the pavement, in some places completely destroying the brick. The conclusion that I draw from the incomplete data at hand is that a pavement constructed of vitrified brick laid with a smooth surface on an unyielding foundation of concrete will stand a great deal of traffic, and if the traffic is light, will last many years, probably longer than any other pavement excepting stone blocks. Nevertheless the pavement is not invulnerable, and when subjected to the severest tests it will not compare with granite block. As to ease of traction and cleanliness brick ranks next to asphalt and is a little more noisy. It affords a much better foot-hold for horses than does asphalt and horses will trot freely over it. In this respect it is much superior to either asphalt or granite blocks. There is a diversity of opinion as to the proper size of the brick and as to whether they should be made from shale, clay or a mixture. Most of the advocates are influenced by financial considerations and it is hard for an outsider to draw correct conclusions. The shale people seem to have had the most powerful argument at the time the specifications were adopted by the city. My opinion is that it makes little difference whether the bricks be made from shale, clay or a mixture provided there is the proper chemical composition so that the bricks will vitrify and provided the bricks are carefully made. I do not consider the size of much importance, although I prefer as large a brick as can be thoroughly vitrified; this maximum size is generally taken as 3x4x9 inches, manufacturers claiming that larger bricks will not vitrify, and as a rule they recommend a size about 2 3-8x4x8 inches. In this connection it is interesting to notice the first brick pavement laid in the city. The intersection of Lake avenue and 53rd street was paved in 1887 with brick made from fire clay, and the size of the brick was 4x12x5 inches. Three years later the balance of Lake avenue from 51st street to 57th street was paved with the same kind of brick. The bricks were bedded in sand on the natural ground without proper foundation. In consequence of this lack of foundation, and because it has been opened in many places and not properly repaved, the street is uneven and in some places is in bad condition, yet where the pavement has been undisturbed the bricks are in good condition and are little worn. Shale bricks are harder and more brittle than clay bricks; clay bricks are tougher, not so liable to chip, but are apt to wear away like sandstone. Some shale will not make good bricks unless mixed with a clay of the proper composition. An example of brick made from a mixture is that laid by the South Park Commissioners on Michigan boulevard, between Jackson and Van Buren streets. This pavement was laid in the best possible manner and is subjected to a very large volume of traffic. The time

that this pavement has been down, two years, is too short to judge of its durability, but I believe it will last for many years, and if it should fail it will prove that the particular make of brick used is not suitable for such heavy traffic. In my opinion the proper place for a brick pavement is in the business streets of small cities, in the retail business streets of large cities, especially where street car tracks are laid, and in residence streets where the residents do not object to the noise of the passing traffic. From the standpoint of a horseman it is less objectionable than any other pavement except a high-class macadam.

WOODEN BLOCK PAVEMENT.

It has recently become fashionable to condemn wooden pavements as being unsanitary and in general as being unworthy of being laid in the streets of a great city. Nevertheless the humble cedar block has its proper place and under certain conditions it is a satisfactory pavement. The reason it is being generally condemned is that for years our city fathers ordered it laid on all sorts of streets without regard to local conditions, and very little care has been taken to see that the pavement was well laid or that the materials were sound. Cedar blocks laid over a sandy soil, where the streets are not sprinkled and where there is little traffic will rot and wear out quicker than they will where they are kept moist and the traffic is heavy. In most cases the destruction of a cedar block pavement is due to the rotting of the wood rather than the wear and tear of the traffic. If sound cedar blocks be laid on a solid foundation and kept constantly wet they will stand a very heavy traffic for several years. The practice is becoming more general of laying the cedar block upon a foundation of macadam. This in my opinion is wise, for the macadam foundation is not only much more solid than the plank foundation formerly used, but is practically indestructible and can be used again and again, and in order to repave the street it is only necessary to lay new blocks on the old foundation. Again in the process of building the macadam foundation the heavy steam roller will thoroughly compact the filling and will prevent the uneven settlement due to badly filled trenches. Since a macadam foundation is good some people have concluded that a concrete foundation would be better. This has not been tried in Chicago, but in other cities where it has been tried the results were bad, as the concrete seemingly causes the blocks to rot very quickly. The superiority of the cedar block pavement over the others already considered is in its cheapness and freedom from noise.

And while new and in good condition it gives a good foot-hold for horses and little resistance to traction. On the other hand, when it gets into bad condition it is one of the worst pavements

to drive over. A cedar block pavement over three or four years old is always filthy, no matter how much care may be taken to clean it. Therefore it is not a proper pavement in a residence street where the city officials or the property owners take the trouble to clean the streets. If, however, the streets are to be left dirty most of the time it makes little difference from a sanitary point of view whether the pavement underneath the filth be wooden block or asphalt. On account of its cheapness this pavement will continue to be used a great deal where property owners do not feel able to pay for a better pavement. In this respect it comes in competition with the cheaper grades of macadam. There are many places where it is better to lay wooden blocks than macadam; these are where there is a clay soil and therefore unsuited to macadam, where there is considerable traffic and where there are street car tracks. It seems absurd to advocate the use of such a pavement on our down-town streets, yet I believe that if properly laid it would be more durable than either brick or asphalt and the cost of renewing the blocks every five or ten years would be small compared to the damage to the nerves of the office workers of the city that is caused by the incessant noise of the heavy traffic over the granite blocks.

MACADAM PAVEMENT.

There are so many kinds and grades of macadam that it is difficult to deal with this subject as we have with the other pavements. The cost of the macadam may vary from 50 cents a square yard to $1.50. It may be the dustiest, muddiest and most unsatisfactory sort of a pavement or it may be almost as clean and quite as smooth as sheet asphalt and be an ideal pavement for a horseman. It may be built so as to need extensive repairs every year, or it may be built so as to stand considerable traffic for ten years without any repairs. Without considering the extremes we may divide the macadam pavements into two grades, the "common" and "high class" macadam, the former costing from 60 to 90 cents per square yard, and the latter from 90 cents to $1.20 per square yard. The "common" macadam roads are built of limestone put on in two layers, each layer bonded with limestone screenings or bank gravel and thoroughly rolled. The total thickness of the pavement varies from 9 inches to 12 inches. The "high class" macadam has a top layer of hard stone or crushed granite from 2 to 4 inches thick and is built in the same way as the "common" macadam except that the granite should always be bonded with a peculiar loamy gravel that is found abundantly in Joliet. The chief objection to the "common" macadam is that the limestone of which it is made is comparatively soft and will wear away under the traffic and the road become dusty and muddy. Its chief merit is that it is cheap, and if the traffic be light it is durable, mere exposure to the weather hav-

ing no effect on it. However dirty these streets may be they are never worse than the cedar block pavements in the neglected parts of the city. It is only fair to compare them with such pavements since macadam streets are seldom cleaned. In fact 90 per cent of the dirt on macadam streets is dirt that has been dropped there and is not due to the disintegration of the limestone. When the wearing surface is made of crushed granite properly bonded and rolled the street will stand considerable traffic for years with very little wear.

If the same attention be paid to cleaning it as is done to other paved streets, and if it be lightly sprinkled three or four times a day it will be as free from dust as any street and will be as free from mud as a cedar block pavement of the same age. The durability will depend on the traffic. On such a street as Michigan boulevard, north of 22nd street, where there is a constant throng of carriages, the pavement will wear down nearly an inch in a year, and the wearing surface will have to be renewed every three or four years. In this case it is an expensive pavement to maintain. Further south on Michigan boulevard, south of 39th street, where the traffic is lighter, this pavement has lasted with slight repairs for five or six years and is still in very good condition. I believe if the question were thoroughly investigated it would be found that the best macadam pavements laid in Chicago have cost no more for repairs and have been quite as durable as the asphalt pavements which have cost twice as much to build. Macadam roads should be built with a very high crown so that the water will be quickly carried to the gutter. The crown should be so high that after three or four or five inches of the center of the street has been worn down there will still be as much crown as is usually given to other pavements. The material should be spread so as to give a uniform surface and cross-section. It is possible to build a macadam street with just as true a surface as is given to an asphalt or any other pavement. This will add not only to the beauty of the street but to its durability as well, for it prevents water standing on the surface and softening the pavement. The most important thing in building this pavement is to roll thoroughly each course, especially the surface. The rolling should be continued until the heavy steam roller makes no impression on the street and a loaded wagon should scarcely leave the marks of its wheels on the surface. One of the advantages of a macadam pavement from the economical point of view is that it can be repaved very cheaply.

After the road-bed is apparently worn out so that it is full of holes and ruts and the center worn down so that the pavement no longer sheds water, the street can be cleaned, the surface loosened with a spiked roller and a new top layer of crushed stone spread to a depth of three to five inches, as may be needed, and this rolled until it is perfectly smooth and solid. All this can be done and the street made quite as good as new for less than one-half the original cost of the pavement. Unlike cedar block pavement, ma-

cadam is best suited to a sandy or gravelly soil; on the contrary, it is seldom satisfactory on a clay soil. Where the clay is full of moisture and is plastic it is impossible to roll the macadam sufficiently; the heavy steam roller will work up the clay beneath the macadam and as the roller moves along it will cause a perceptible wave in the surface of the street; this, of course, loosens the macadam as fast as the roller compacts it. Another objection is that where the clay is soft it is apt to ooze up through the crushed stone. This may occur during the construction of the road or a year or more afterwards. It is very apt to occur in the spring of the year when the frost comes out of the ground. This trouble can be prevented by spreading on the clay sub-grade a layer of sand, ashes, stone screenings or any other fine material that will absorb the water and mud and will prevent the soft clay from coming up through the stone. Again in a country where the cross streets are unimproved wagon wheels laden with the sticky clay will pick up the smaller stones and will drop them again somewhere else, and the street soon becomes a series of humps and hollows. In such localities where a cheap pavement is wanted cedar blocks are by far the more satisfactory. Macadam should never be laid on streets where there are car tracks, as it is not practicable to give the pavement sufficient crown, and then ruts always form near the rails, as so many people habitually drive at a regular distance from the tracks.

Macadam pavement is especially adapted to residence streets in suburban towns where the property cannot afford expensive pavements, the traffic is light, and hence macadam is durable and truly economical. The quality or grade of the macadam should depend on the ability of the property owners to pay for it. In many cases it is wise to put down a cheaper grade at first and then after an interval of ten or twelve years when the pavement is badly worn put on a new wearing surface of crushed granite. A "high class" macadam pavement is suitable for nice residence streets where there is considerable pleasure driving and where the property owners have sufficient enterprise to keep the street clean and in good condition. Macadam is used a great deal by the Park Commissioners of Chicago, especially Lincoln Park and South Park. The reason for this is that these park drives and boulevards are chiefly for the pleasure of horsemen, and the Park Commissioners are so situated that they can keep these roads in perfect condition. Where the traffic is so great as it is on some of the boulevards this is an expensive pavement to maintain and perhaps it is an extravagance, nevertheless for a pleasure drive a perfectly maintained macadam is the best pavement that has ever been built and the property owners and the Park Commissioners can afford to pay for it. This paper is already too long for your comfort, but more has been omitted than written. It would be interesting to go more into details on several of the topics, to be more explicit in methods of construction, to consider more definitely the cost of the pavements and the cost of maintenance and repairs, also the matter of

opening pavements for underground work and repaving again, but I will leave these points to be brought out in the discussion which will follow.

DISCUSSION.

President Wallace: Gentlemen, Mr. Hill has given us a very interesting and practical paper, and I think it is a paper that ought to be very fully discussed. The question is now open for discussion. Mr. Brown, you know something about pavements and streets. Cannot you give us information on this question?

Mr. Brown: Mr. Hill's experience and mine are so much in the same line that our opinions are very similar. I do not think with Mr. Hill that cedar blocks would be as durable as brick if laid right, but they would be as cheap if laid right and, considering all things, better.

They must be laid with a smooth, unyielding foundation, and this foundation must be kept smooth, the blocks to be renewed when they are worn down. To accomplish this I believe concrete is necessary, and that in most cases the blocks would wear down before they rot out.

In December, 1891, the Wisconsin Central paved around its depot on Harrison street with square cedar blocks on two-inch pine and eight inches of macadam. This is yet in fair condition and the top could be replaced at small cost. At the same time the city paved the opposite side of the street with cedar on two-inch hemlock and the street has been in wretched condition for two years. The planks have sunk unevenly. I notice that about 70 per cent of the planks are good on ripping up old streets for repaving, but they do not lay smooth on account of trenches, etc. On Wabash avenue some planks were six inches higher than those next them and of course the paving was uneven and seemingly worn out. We will have the same trouble with cedar on macadam.

President Wallace: I would like to ask you gentlemen that are interested and know something about the practical method in city street work in reference to the approximate cost of the renewals of macadam pavement. I own two pieces of property on a residence street, in which the street was paved with an ordinary macadam about six or eight inches, I think, on sand and gravel. The street was repaved after getting the consent of the property owners, and the assessment was something like \$3.50 to \$4 a square yard, and the paving consisting in distributing some ordinary limestone rock in the holes or in the depressions of the old macadam, then in sprinkling about two or three inches of granite on top and rolling the same.

Mr. Hill: I think Mr. Brown was engineer on that street.

President Wallace: It is such questions as that that strike the average property holder that has assessments to pay, and I was in hopes that something would develop to-night that would be of interest to those that have to pay assessments.

Mr. Brown: I might say it is pretty hard work to give any definite information with regard to any certain street in any such case as that, but the data are on hand at the City Hall.

President Wallace: Is it considered better practice to leave the old macadam in than to tear up the old macadam and lay it anew when the street is paved?

Mr. Brown: I think it is better to leave it if it is properly filled up. A property owner when he figures on his $3 or $4 a square yard does not figure on the intersection, nor that he gets in so much curb at the same time.

Mr. Hill: If you will permit me to go into the ancient history of Ellis avenue—that street was originally macadamized in '86 or '87, and the engineer in charge wished to build with a flat crown. The result was that the street was never satisfactory, the water did not drain off and it did not do nearly as well as other streets; it was always muddy. Now, the original pavement only had a wooden curb in; when this new assessment was made it was based on granite concrete curb, which cost about 75 cents a running foot, and the specifications, I think, were properly drawn, which provided for filling up all the holes and putting on an average of two or three inches of limestone to give a surface. This limestone should have been properly bonded with fine screenings and rolled and tamped the same as a new street would be, and then the granite put on from two to three inches and thoroughly rolled. In my opinion the specifications as drawn were quite correct. I am familiar with the specifications because I figured on the work and got left. Of course the competing contractor did not do his work right. (Laughter.)

President Wallace: I simply brought up an actual case, endeavoring to make it a hypothetical question, without reference to any particular street.

Mr. Brown: Have you asked for your rebate yet?

President Wallace: No.

A Member: I would like to ask Mr. Hill if he noticed the construction of the pavement on Adams street, near Clark?

Mr. Hill: It is granite block pavement.

A Member: The reason I asked is, that where the carette runs, a groove is worn, and it is hammered down as asphalt would be.

Mr. Hill: I have noticed the same thing. I did not see the street built, but I practically know that it was built on a foundation of macadam, probably six inches of macadam, covered with Joliet bank gravel, or some other kind of gravel, and rolled, then a layer of sand and blocks laid in the sand. As to why it should give way I do not know, excepting probably that as a rule they put too much sand, the sand layer is generally too thick. It is cheaper than the stone that it goes underneath, and makes up for deficiency, and if you have too much of a bed of sand, the blocks are apt to pound down into it.

President Wallace: It seems to be well accepted that any form

of block pavement, it don't make any difference whether cedar block or granite or brick, that the only purpose of the block is to form a wearing surface, and that without the other feature of a good pavement, which is the foundation, that any of them are liable to be failures. As I understand, the two principles of a good pavement is, first, a perfect foundation, and second, a perfect wearing surface. Where you have the one without the other you have a failure. It seems to me that the greatest difficulty in the way of maintaining a proper pavement in a city like Chicago is the incessant tearing up of streets. There is hardly any form of pavement that will stand tearing up every two or three years for water pipes, gas pipes, or sewerage and repairing and replacement of same.

Mr. Liljencrantz: That seems to be particularly the case when the wooden pavement is used with a plank support. The planks, when pipes are laid down, are cut off, and the support is naturally destroyed, and the result is that the streets in such cases look very much alike. For instance, Wabash avenue, a good portion of it, is just in pits and holes all the way through.

President Wallace: The great trouble is that you do not get continuity of your support transversely of the street. Your ditches run lengthwise with the street, and when you restore that pavement again you fail to get the continuity of bond which you had in the original pavement, and you must necessarily have irregularities in it.

Mr. Hill: On that point I wish to say, contrary to general opinion, that I believe that any pavement can be taken up and trenches made in the street and refilled and pavement put back so that it is just as good as it was before, but the cost of it would be equal to putting down that much new pavement, that is, the labor and care and trouble would cost fully as much as the material you saved in putting back the old pavement If you look at the park boulevards, especially the South Park, you will find that they have had their pavements opened a great many times, and there are no irregularities in it. Of course that is true not only of macadam pavements, but it is true of any. The truth is that the corporations who lay these pipes do not employ expert laborers, and they do the work as cheaply as they can, and work that is cheaply done is never very well done.

Mr. Maddock: I agree with what Mr. Hill says in regard to repairs. I have had to take up cedar block pavements for water pipes and sewers to be laid in the street, also brick and macadam pavements, and I have put them back, with a force of men trained for that purpose, and we have never been able, in the course of three years, to tell where the excavations were made, and by training your men for the work it is not expensive either.

President Wallace: Is that in the city of Chicago?

Mr. Maddock: No, sir. There is another matter which was referred to incidentally in Mr. Hill's paper regarding parks. Now,

property owners are in the habit of going to the park board and park engineers to get information on pavements. My observation leads me to think that this is wrong. Parks are only used about eight months, at most, in the year; they are only used in fair weather, and there is only pleasure driving in the parks, while the streets are used by the public; even the residence streets are used twelve months in the year for all kinds of traffic. They have a different duty to perform than the streets put down by the Park Board, and what will answer for the park will not answer for the residence streets of a town.

President Wallace: In reference to park pavement, there is one very interesting question that may come up in that connection in a very few years, and that is the difference in character of the vehicles that are used on those roads. Five or eight or ten years ago you could see our park drives lined with carriages, and now you see them lined with bicycles with pneumatic tires, and our carriages are using pneumatic tires, and the presumption is that when we have motocycles they will have pneumatic tires, and it seems probable that the character of the traffic in our parks will be revolutionized.

From a professional standpoint and a practical standpoint I am more interested in the character of the paving in front of freight houses that I am in any other form of pavement, and it has been quite a problem with the company I represent. We have large freight houses in Chicago, St. Louis, Louisville, Memphis and New Orleans and we have not succeeded yet in getting a satisfactory pavement. The only thing that has given anything near satisfaction has been granite blocks on macadam, or where we could not obtain the macadam economically, on a cinder slide foundation. We have used in Chicago Sioux Falls granite blocks, counting freight and everything, for less than $2 a square yard on 8 or 9 inches of cinder. Mr. Hill's paper to-night is very interesting to me for the fact that in a very short time I shall have repavement to do in East St. Louis. Some of the companies are using vitrified brick and having that laid on a concrete foundation, I think, for as low as $1.40 a square yard.

Mr. Hill: You ought to get it cheaper than that there.

President Wallace: The company would have, well, I presume altogether it would amount to about two miles of driveways through the different yards, team tracks and so on, what was formerly the Cairo Short line. It had made all paving of four-inch plank and from figures that I made a short time after I took hold of that property I am satisfied that there is more money spent on that oak plank, on its renewals, labor of taking up and putting down, than the laying of a first-class pavement would cost, that is, figuring the maintenance for a series of years. The one form of paving that I was considering there—we have a stone quarry of our own—was, making an excavation of about eighteen inches deep and putting in ordinary rip-rap stone, something like the foundation for

an old-fashioned Telford pavement, and then filling on top with crushed stone prepared for that purpose, and then putting screenings on top and rolling it. The great trouble with the pavement in front of freight houses is, that teams back up and turn right in front of freight house doors from day to day right in the same places, and the result is that the circular action of the wheel gives a leverage—a grinding effect that will destroy almost any kind of pavement except granite block.

Mr. Liljencrantz: Mr. Haller is present. I think perhaps he can tell us something about the prevailing pavements in Germany.

Mr. Haller: Wooden pavements, owing to their short duration and comparatively high cost, are rather scarce in Germany and are mainly found in such places only, where, as on school grounds, it is desirable to have as little noise as possible. The blocks of pine wood are rectangular or of pyramidal shape, crossjoints laid tightly, lengthwise joints about one inch wide, filled with asphaltum.

Asphalt pavements are very popular in German cities and are laid with great care.

Streets with heavy traffic have hard stone pavements, the top of stones being cut exactly rectangular with straight edges.

Brick pavements have also been introduced in Germany of late and are said to give good satisfaction.

As regards the country outside of cities, Germany abounds in good macadamized roads, rolled with heavy steam rollers.

Special care is taken to use the very best building material only, to supply all streets and roads with a good, substantial and durable foundation, to give a perfect system of drainage, and to preserve them in the best possible condition generally. To accomplish this end, there are even to every few miles of country roads special overseers, whose only duty it is to constantly inspect the distance assigned to their care and continuously keep that portion of road in good condition.

I may add that most of the country roads in Germany are provided with a sidewalk, and that all of them are lined on both sides with trees.

A Member: I would like to know if there is any Belgian block or square stone used in Chicago?

Mr. Hill: I do not know of any. The nearest approach to the granite dressed pavement is from Adams to Jackson on Michigan. The blocks used there were dressed very carefully and made as square and even as they could get them. Of course they did not approach regular form.

President Wallace: There is a large kind of square block pavement, something of the Belgian form, in New Orleans, and the blocks in a great many of those streets are from about 16 to 18 inches square with diagonal grooves across them, and I have seen a great deal of that pavement there that seemed to be originally of those square blocks put upon ordinary sand and gravel foundation.

Mr. Noble: Are those pavements being laid now?

President Wallace: No, sir, that is the old style.

Mr. Noble: That was before the war?

President Wallace: Yes.

Mr. Noble: I would like to hear Mr. Hill discuss the relative merits, here in Chicago, of block pavements and brick pavements on concrete and macadam foundations.

Mr. Hill: In regard to the wood, I can not back up what I said from my own experience, and it is only what I have heard. It has been tried in Omaha, Kansas City and other places, and it generally has the effect of rotting the wood. Concrete, I know from reading, is used a great deal in London and Continental cities under wooden blocks. They have entirely different kind of wood, and it is perfectly satisfactory there.

In regard to the relative merits of concrete and macadam, with, say, brick pavement, I much prefer concrete. That is, it is much preferable to macadam foundation as usually laid. If the macadam foundation were laid right, very well laid to give a very smooth surface, it would be in my opinion as good as concrete and it would cost as much, but it is not laid that way as a rule. Where it is put under cedar block pavement they do not roll it enough, they do not give it a smooth, uniform surface, the result is that they put on a varying thickness of sand to lay the thickness of blocks on. Now your granite blocks will vary in depth, thus it is necessary to have a good bed of sand and then a macadam foundation is satisfactory.

I am not prepared to say that concrete would be a good thing as a rule to put under granite. I doubt it, unless you are in some of these down-town streets where there are street car tracks, electric conduit manholes, and so many other obstructions that you can not roll the streets. In that case you had better get your blocks of uniform depth. With brick it is very important that it should be laid very true; one brick should not be a quarter of an inch higher than another, because if it gets a blow it will break the edge of the brick and for that reason it is essential that the sand cushion should be very thin, it should not be over an inch, and therefore you want a smooth surface under the sand, and you can be sure of getting a smooth surface with concrete foundation, therefore I should put concrete under the brick.

President Wallace: You made a statement that cedar blocks lasted longer when they are moist with sprinkling and on a wet foundation, and do not last so long on a concrete foundation, presumably because of the greater moisture against the bottom of the wooden planks.

Mr. Hill: I did not give any theory.

President Wallace: What is your theory about moisture?

Mr. Hill: It must not be alternate. You want to sprinkle the streets once in so often and keep them moist. I heard a contractor tell about South Water street, which had been paved with sawed wooden blocks seven inches deep; he could not remember how many years they were down there, but a great many years. After-

wards he took up that pavement and put down granite pavement, and the wood had worn down from seven inches to four inches, and yet what was left was perfectly sound. They have an enormous amount of traffic there, the street is crowded with horses all the time. On the other hand I know a cedar block pavement, in fact it is the bit of pavement running down the Illinois Central station at Oakland. In that block there is seldom a horse or carriage on the pavement at all, yet five years after that pavement was laid the bottom of the blocks were all eaten out with dry rot. It was laid on a sandy soil and dried out.

President Wallace: There are some woods that stand moisture a great deal better than they do dryness. For instance the black and yellow cypress in the south will last a great deal longer near the water, where it is in a moist climate, than it will if brought up here where it is dryer. And one reason why I asked Mr. Hill is to know whether cedar has that same peculiarity.

Mr. Hill: I think it is well known that cedar will last longer in wet ground than almost any other wood used.

President Wallace: I mean where it is subject to alternate moisture and dryness, as in ordinary structures.

Mr. Maddock: I had some experience with cedar blocks that will substantiate what Mr. Hill said in regard to moisture. I think it is absolutely necessary that cedar block pavements be kept moist. There are reasons for it; I think I can demonstrate it. When the sun shines brightly in clear weather, the blocks shrink and the sand that has been rammed around them settles down around the bottom of the block. Dirt and other material settles in and then when a rainstorm comes the blocks absorb the water and swell, and if the curb does not give laterally, that is, if it does not throw the curb out of line, the blocks will lift, will be thrown up. I have had them thrown up so you would suppose there had been an eruption of a volcano. If they are kept moist continually, not soaking wet, they last longer, they do not decay as they will if they are alternately wet and dry. In regard to the point that Mr. Hill makes, as I understood him, about macadam under cedar blocks, I differ with him. In my opinion, at least on sandy soil, I find it very hard to get a surface of the cedar blocks with macadam foundation. It looks to me that money spent for macadam under cedar blocks in a sandy soil is entirely thrown away. You have, to commence with, sand. It has to be flooded and pressed so as to be unyielding, and you have one of the best foundations that you can secure, and the hemlock plank will ordinarily last two sets of blocks; if you have to take up blocks laid on a macadam foundation, the foundation has to be prepared over again. Another trouble with macadam foundations is to get all the crevices and openings filled with the sand. The sand will settle down afterward and leave depressions in the blocks.

Mr. Condron: I want to ask a little about brick paving. There were some remarks by Mr. Hill about the different qualities of brick, shale and clay, and the mixture of shale and clay, and he gave as

his opinion that either shale or clay are equally good, provided the brick was satisfactorily vitrified. I want to ask if he is able to give us his ideas of how a brick can be judged before it is laid in the paving. That is, if any of the recognized tests give to an engineer data by which he can judge of the quality of the brick before he lays it.

Mr. Hill: I am not at all expert in this matter. I do not think I can give you any valuable advice on that. There are certain tests that are generally specified by the city engineers. I think the specifications in the City of Chicago are quite correct, except I do not think it is necessary to put the word shale in. The usual tests are to see how much water it will absorb in a certain number of hours, specific density; put it in a rattler with a piece of cast iron and see how much abrasion it will stand. You will get the relative merits of bricks in that way and engineers have arrived at a certain scale, by which they claim that brick that will stand a certain percentage in the test is a good brick. People who have handled them a great deal pretend to know when they see a brick whether it is good or bad.

Mr. Condron: The reason I put this question is that I have been called on to make quite a good many brick tests. There is a very wide range in the results of these tests which show a number of different things. I find that brick that will stand the usual abrasion test very well, will sometimes crush all to pieces under a comparatively light compression test. Not very long ago when I was making a series of tests, there was a lot of bricks sent me with the request that I include them in the tests, as the maker wanted to know the relative quality of his brick. He did not speak very highly of them himself, and to look at them, they looked like a very soft brick, in fact, you could readily scratch them with a knife. I did not expect that they would show up well, but they stood the abrasion test almost as well as any brick I have ever tested, but under the compression test they did not explode like hard brick do when you have good bearing surfaces, but they pulverized under a very low load. The question arose in my mind at once, would not that be a good brick in wearing? Now the specifications of the different city engineers would have thrown out these bricks, because they would have absorbed too much moisture, and failed under the specification for compressive strength. But from the fact that the brick resisted abrasion so well would it not wear well in a pavement? I have made a good many tests, and have discarded the use of cast iron scrap, simply rattling the brick by themselves, or with other brick for comparison. Cast iron scrap is never alike in two tests and consequently you have no way of comparing.

I have noticed the one block of brick pavement on La Salle street; it was put down about two years ago, as I remember, and there was considerable other pavement laid in our down-town district about that time, and I do not recall any pavement in that district that looks as well as the one block of pavement on La Salle street. I think it has received about as hard wear as any of the pavements around it.

I think that that block is a very good argument for brick pavement. It makes less noise and is easier for traction than granite. Granite blocks wear splendidly, but they also wear out horses and they wear out tires, and the question is, if an easier pavement is not really a more economical pavement all around.

Mr. Liljencrantz: From what has been said I would draw the conclusion that one of the most important things is the proper laying of the pavement, and probably Mr. Downey, the new commissioner, has taken the first step by sifting out the bad inspectors. We can look for better pavements hereafter.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

SPONTANEOUS IGNITION OF COAL.

Summary of a Paper by Vivian B. Lewes, F. I. C., F. C. S., from the Transactions of the Society of Arts.

The heating of masses of coal exceeding 2,000 tons has led to such inconvenience and loss in shipment and storage as to render the question of spontaneous ignition a serious one and in 1875 the losses of life and property were so great as to demand attention from a royal commission. The report of this commission had little beneficial effect, as is shown by the fact that in the nine succeeding years 57 coal laden vessels were known to have been lost from this cause. The trouble is greatest at sea, but is by no means unimportant in storage of coal.

The greatest influence in the heating action is carbon, which acts to attract and condense gases to a degree depending upon the fineness of division of the carbon, new coal sometimes absorbing three times of its volume of gas. The action is influenced greatly by temperature. When the carbon of coal absorbs oxygen, the compressed gas becomes very active chemically and combines with the carbon and hydrogen of the bituminous portions, converting them into carbon dioxide and water vapor, with a rapidly increasing temperature, which finally reaches the igniting point. The temperature of the coal before the action commences has an important influence, an analogous case being that of oily waste or cotton, which, if warmed to 130 degrees Fahrenheit, will ignite in one and a quarter hours, whereas at ordinary temperatures does not ignite within several days.

The earliest theory of spontaneous ignition of coal was that the heat was due to the oxidation of pyrites, which was shown to be erroneous twenty years ago, but in spite of this the idea is quite generally accepted at the present time. Dr. Percy showed in 1864 that oxidation of the coal had much to do with the action There is considerable action, however, between oxygen and finely divided portions of pyrites with efflorescence, and from this action the opinion has prevailed that the heating is due to the oxidation of the pyrites. The only way in which pyrites in the cleveage of coal can assist spontaneous ignition is that when they oxidize they swell and cause disintegration of the lumps of coal, so exposing fresh surfaces to absorb oxygen and afterward carry on chemical action. I have carefully determined the igniting point of various kinds of coal and find that—

Cannel coal ignites at 690 degrees Fahrenheit.

Hartlepool coal ignites at 766 degrees Fahrenheit.

Lignite coal ignites at 842 degrees Fahrenheit.

Welsh steam coal ignites at 870 degrees Fahrenheit.

Heating does not take place as a rule with newly mined coal unless piled in unusually large heaps. It at once commences to absorb oxygen from the air, but in small heaps the circulation around the lumps keeps down the temperature. After repeated handling, when the coal becomes powdered, as in its loading upon ships, the large surfaces exposed freshly to the air cause rapid absorption of oxygen and consequent rise of temperature.

On examining the evidence to be obtained as to the conditions under which spontaneous ignition of coal usually takes place, it is found that the liability increases with:

First. The increase in mass of coal.

Second. The ports to which shipments are made; 26,631 shipments to European ports in 1873 resulted in ten casualties, against sixty from 4,485 shipments to Asia, Africa and America. The increase of temperature in the tropics converts a slow action into a rapid one.

Third. The kind of coal. Pyrites has no heating effect, and a sure guide is to be found in the quantity of moisture present in an air dried sample of coal. The higher the amount of moisture held by the coal after exposure for some time in dry air the greater will be its power of absorption of oxygen and its liability to spontaneous heating.

Fourth. The size of the coal, small coal being more liable to this trouble than large, on account of the greater surface exposed.

Fifth. Shipping or storing coal while wet. At first external wetting retards the absorption of oxygen, but the presence of moisture afterward increases the action of the already absorbed oxygen upon the hydro-carbons of the coal and so causes a serious increase in the heating.

Sixth. Ventilation of the mass of coal. Ventilation increases the difficulty unless cool air is furnished continuously and freely throughout the coal.

Seventh. Rise in temperature. Anything which tends to increase the initial temperature hastens the chemical action. Causes can sometimes be traced to steam pipes, boiler flues and warm walls.

Having now discussed the chemical and physical conditions which lead to the phenomenon known as "spontaneous ignition," we can formulate precautions which will tend to prevent such disasters.

1. The choice of coal for storage or shipment. The coal should be as large as possible, free from dust, and with as little "smalls" as can be. It is better as free from pyrites as possible, and it should contain, when air dried, not more than 3 per cent of moisture.

2. Precautions to be taken in storing or loading. The coal store should be well roofed in and have an iron floor bedded in cement; all supports passing through and in contact with the coal should be of iron or brick; if hollow iron supports are used they should be cast solid with cement. Coal must never be loaded or stored

during wet weather and the depth of the coal in the store should not exceed eight feet and should only be six where possible. Under no conditions must a steam or exhaust pipe or flue be allowed in or near any wall of the store, nor must the store be within twenty feet of any boiler, furnace or bench of retorts. No coal should be stored or shipped to distant ports until at least a month has elapsed since it was brought to the surface. Every care should be taken during loading or storage to prevent breaking or crushing of the coal, and on no account must a large accumulation of small coal be allowed. These precautions, if properly carried out, would amply suffice to entirely do away with spontaneous ignition in stored coal on land.

G. M. B.

COMBUSTION OF BITUMINOUS COAL BY MEANS OF HOT AIR ADMITTED ABOVE THE GRATES.

Abstract from Discussion of a Paper on Combustion in Marine Boilers, by J. R. Fothergill, read before the Liverpool Eng. Soc. Jan. 8, 1896. Trans. Liv. Eng. Soc. 1896.

Mr. F. Gross (John Brown & Co., Sheffield): * * * It is this admission of above the grates which, with our suction draft, gives the best results, and in some of our steamers we have carried it to an absolute extreme, i. e., with bituminous coal we practically admit the whole of the air required for combustion on the top of the fire with the result incidental; never sought for, but entirely incidental, that no smoke whatever is the result of that system of the admission of the air. The only air we admit through the grate is just a small quantity of cold air to keep the grate in a satisfactory condition. The bulk of the air is, of course, always hot. Now, when you put the volume of air practically necessary for combustion of the coal on the top of the fire at a heat of from 200 to 300 degrees you will find that, unexpected as it may be, the smoke question solves itself. You can come at any time to our works and you will see ten boilers developing 10,000 horse power, but you will not see a single bit of smoke. It is all due to what I have said. We happen to have a very convenient means of heating the air by what would otherwise be waste heat.

It is quite a mistake to suppose that all the air must go through the grate. * * * With bituminous coal there is no question that the admission of hot air on the top of the grate through perforated baffle plates is just the means of obtaining the best analysis of chimney gases, a smokeless condition and the greatest economy. * * * I would only point out to you that when burning at a rate of 45 pounds per square foot of grate the boiler efficiency, by the means I have named, is as high as 75 per cent. Of course it is still higher at a lower rate of combustion.

And as I have pointed out results that would have been thought quite incredible three or four years ago are already obtained in that direction, and the Scotch boiler, under new conditions, will take a great deal of beating.

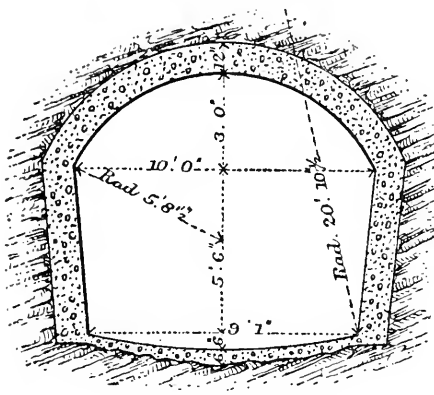
C. F. W.

OBSERVATIONS ON THE FLOW OF WATER IN THE NEW AQUEDUCT FROM LOCH KATRINE: GLASGOW CORPORATION WATERWORKS.

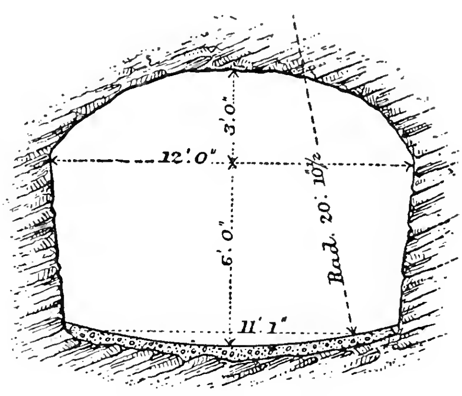
By Alexander Fairlie Bruce, M. Inst. C. E.

(*Minutes of the Proceedings of the Institute of Civil Engineers, Vol. CXXIII.*)

The object of the following notes is to give the results of some observations made by the author on the flow of water in the new aqueduct connecting Loch Katrine with Glasgow, with the view of determining the value of the coefficient of friction n, in Kutter's



SECTION WITH CONCRETE LINING.



UNLINED SECTION.

Scale, ¼ inch to 1 foot.

Fig. 116. Fig. 117.

formula,* for such channels and of ascertaining the comparative value of velocities obtained by the use of floats.

For about 53 per cent of its length the aqueduct is lined with concrete (figure 116), which was built in the usual way, in 12 or 15 feet lengths, generally the former. Open frames of 6-inch by 2-inch battens were first placed in position, and ¾-inch tongued and grooved boards, smeared with soft soap, nailed to them horizontally as the concrete was filled in. Every possible precaution was taken by working with spades to obtain a good face, and except where some defects showed themselves no rendering was afterward necessary. The whole of the invert was concreted and floated with a steel float, whether lining was required or not, and, as shown in figure 117, the unlined portions are made two feet wider than where lining is required in order to allow for the additional friction. This increases the available area when the aqueduct is running full (i. e.,

---

*
$$C = \frac{41.6 + \dfrac{1.811}{n} + \dfrac{0.00281}{i}}{1 + \left(41.6 + \dfrac{0.00281}{i}\right)\dfrac{n}{\sqrt{m}}}.$$

C—Coefficient of discharge.
i—Sine of the inclination.
n—Coefficient of fraction.
m—Hydraulic mean radius in feet.

a foot above the springing level of the arch) from 64.866 square feet to 78.280 square feet, and the hydraulic mean radius from 2.869 feet to 3.106 feet, or 21 per cent and 8.25 per cent respectively. These increased values were fixed upon by Mr. J. M. Gale in designing the work, on the basis of the values of n, found by him experimentally for the lined and unlined portions of the old Loch Katrine aqueduct, which proved to be 0.0184 and 0.025 respectively.

The part of the aqueduct selected for experiment is perfectly straight, extending from the access chamber at High Lettre to that at the Blairgar aqueduct bridge, a distance of 1,921 yards. Rather more than half of it is lined, and the gradient is 1 in 5,500. The depth of water flowing in the aqueduct was measured on the gauge-rods in the chambers, and the true mean velocity was arrived at by dividing the quantity of water measured over the gauge-weir at Mugdock reservoir* by the area of flow in the aqueduct. The results are given in table XXXVII in the appendix.

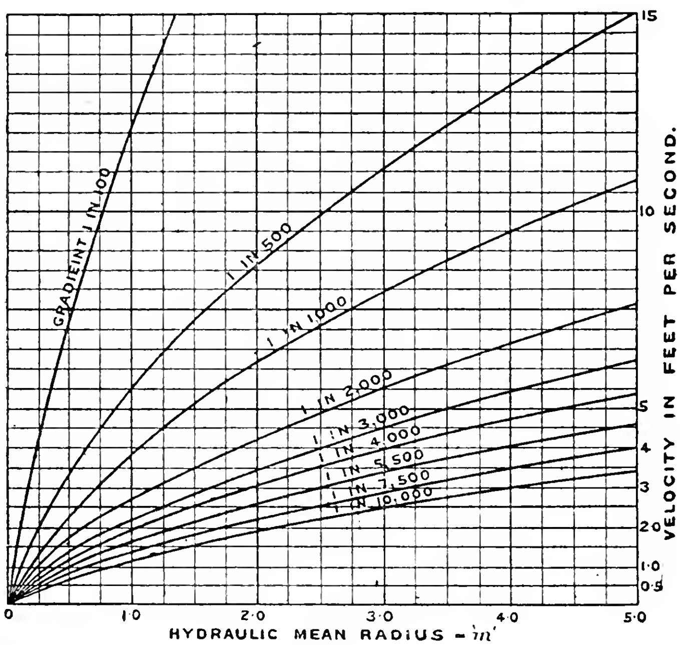


FIG. 118.

For comparison with the above experiments surface floats were used, made of circular pieces of wood 1¾ inch diameter and ¾ inch thick, and rod floats 1 inch diameter and 2 feet 2 inches long, weighted with lead so as to be immersed to the extent of 1 foot 9½ inches and painted white; hooks were screwed into the top to enable them to be more easily recovered, and each set of floats was numbered from 1 to 10. The floats were placed in the water at intervals of between thirty seconds and forty-five seconds in the

* Calculated according to the formula: $Q = 3.421\, l\, \sqrt{h^3}$ where Q is the quantity of water discharged in cubic feet per second. l is the length of the weir in feet, and h the head above its lip in feet.

middle of the chamber and timed as they entered the tunnel. Five or six of each series were usually between one minute and two minutes slower than the mean, owing, probably, to their having been caught and detained in eddies in the unlined portion. These were rejected and the results given in figure 116 are the means of the four or five remaining, which usually came within thirty seconds of each other.

It would appear from these experiments that velocities obtained by the use of the surface floats are, in such cases, unreliable; those in the present instance giving a result, if Darcy's formula* be applied to calculate the mean from the surface velocity, about 18 per cent less than the correct figure. On the other hand, though the velocities obtained by the rod floats fluctuated somewhat they gave a mean result of only about $\frac{3}{4}$ per cent less than the true mean, which is a sufficiently close approximation for most purposes.

The values deduced for n vary between 0.0119 and 0.0129, the mean being 0.0124, except in one or two cases, where, perhaps, there was some slight uncertainty in reading the quantity flowing over the gauge-weir, the variation being generally only about 0.0001 on either side. This value is half way between those given by Kutter for "unplaned planks" and "ashlar and brickwork," and agrees with Mr. W. J. B. Clerke's figures, for the aqueduct in connection with the Tansa waterworks for the supply of Bombay.† The large value obtained by Mr. Gale in his experiments on the lined portion of the old aqueduct is no doubt due to its being lined with masonry, the joints of which are very open, all the mortar having been washed out of them. This causes the formation of eddies, thereby greatly increasing the surface friction. The velocities of discharge have been calculated, for various values of m and i when n—0.0125, and the velocity curves (figure 118) have been plotted them.

Some observations on the discharge of the siphon pipes across the Blane Valley are given in table 11 in the appendix. There are two lines of 48 inch pipes, 3,557 feet long, which, at the dates of the experiments, had been laid between two and three years and charged with water four months, so that they had been exposed to a certain amount of corrosion. The volume discharged was measured at the gauge basin, as in the case of the aqueduct experiments, and the levels of the water, both at the valve chamber where it enters the pipe and at the basin where they deliver it again to the aqueduct, were carefully measured. The quantity delivered by the pipes for various hydraulic gradients is given in table XXXVIII and is practically identical with that obtained by calculation, using

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* $Vm = Vo - 25.4 \sqrt{m \times i}$.
Va = mean velocity in feet per second.
V = surface.

† Minutes of Proceedings Inst. C. E., vol. CXV, p. 27.

Professor Unwin's modification of Darcy's formula for new pipes coated with pitch;* viz., $v = 69\sqrt{di}$, where v is the velocity of the water in feet per second, d the diameter of the pipe in feet, and i the hydraulic gradient.

In conclusion the author desires to express his indebtedness to Mr. Gale, chief engineer to the Glasgow Corporation Water Works, for the facilities granted him for making the above experiments.

APPENDIX.

TABLE XXXVII.

OBSERVATIONS ON THE FLOW OF WATER IN THE AQUEDUCT AT DIFFERENT LEVELS.

Depth of Water in Aqueduct.	Cross Sectional Area of Stream.	Discharge over Gauge Weir.	Mean Velocity.	Hydraulic Mean Radius. m	Coefficient of Discharge. C	Coefficient of Friction. n	Surface Velocity by Floats.	Mean Velocity by Weighted Rods.
Ft. In.	Square Feet.	Cubic Ft. per Second.	Feet per Second.	Feet.			Feet per Second.	Feet per Second.
1.8⅝	14.225	26.620	1.8714	1.2273	125.35	0.0123	2.1139	....
2.1⅞	18.299	37.863	2.0691	1.4713	126.58	0.0125	....	....
2.1⅞	18.299	38.567	2.1076	1.4713	128.93	0.0123	....	....
2.2⅜	18.692	41.423	2.2161	1.4896	134.59	0.0119	....	....
2.2½	18.788	39.986	2.1283	1.4982	128.88	0.0124	....	....
2.2⅝	18.888	40.702	2.1549	1.5002	130.41	0.0123	....	....
2.3¾	19.765	42.890	2.1750	1.5469	129.62	0.0124	2.1836	2.1631
2.5	20.774	45.832	2.2062	1.5990	129.33	0.0125	2.2600	2.1986
2.5	20.774	45.832	2.2062	1.5990	129.33	0.0125	2.2554	2.2309
2.5	20.774	45.832	2.2062	1.5990	129.33	0.0125	2.2422	2.2095
2.5	20.774	45.832	2.2062	1.5990	129.33	0.0125	2.2621	2.2020
2.5	20.774	45.832	2.2062	1.5990	129 33	0.0125	....	2.1970
2.5⅛	20.857	46.582	2.2334	1.6071	130.58	0.0125	2.2571	....
2.5¼	20.931	46.582	2.2255	1.6105	130.14	0.0125	2.2340	....
2.5½	21.132	47.335	2.2451	1.6208	130.72	0.0124	2.2275	2.1911
2.5¾	21.330	48.092	2.2547	1.6270	131.02	0.0124	2.2466	2.1680
2.8¾	23.687	53.504	2.2588	1.7403	126.92	0.0129	2.2335	2.2215
2.11¼†	25.627	53.504	2.0845	1.8122	135.58	0.0121	2.1271	2.1054

†The sluice on one of the Blane siphon pipes was closed, so the water was dammed back to a surface slope of 1. in 7,711.

*Encyclopædia Britannica—Hydraulics, p. 485.

TABLE XXXVIII.

DISCHARGE OF 48-INCH PIPES FOR VARYING HYDRAULIC GRADIENTS.

Ruling Gradient.	Discharge of Pipe Measured at Gauge Weir.	Velocity.	Discharge Calculated by Formula.	Velocity Calculation.
	Cubic Feet per Second.	Feet per Second.	Cubic Feet per Second.	Feet per Second.
1 in 5,928	1,352.6	1.798	1,347.6	1.787
1 in 5,081	1,437.6	1.908	1,455.7	1.930
1 in 3,785	1,628.9	2.161	1,686.6	2.237
1 in 1,423	2,750.0	3.649	2,750.9	3.648

NOTES ON SOME FAILURES IN SEWER PIPES.

By John H. Parkin, Assoc. M. Inst. C. E.

(*Trans. of The Liverpool* (*Eng.*) *Engineering Society, Vol. XVII.*)

The materials used for modern sewers have received much attention from engineers, and, as generally selected, are admirable for the purpose.

It frequently happens, however, in the construction of sewerage works that the materials are subjected to influences not in proportion to their strength or elasticity, or to the uses for which they were intended, and careless workmanship, with inefficient inspection, may often cause a failure in the most carefully designed scheme.

One of the requirements of a good sewer is that it should be practically watertight. This is especially important where the sewers are laid in a wet subsoil and the sewage has to be pumped. It is also important where the sewers are laid in ground above the subsoil water, should the pumping be intermittent. If the sewer has a free outfall, as into a river or the sea, the admission of a certain amount of subsoil water may be advantageous in keeping the sewer fresh and in lowering the level of the water in the land.

In pipe sewers leakage principally occurs at the joints.

Clay is sometimes used as a jointing material, but it is easily removed by the action of running water and is unsuitable for resisting pressure.

Pipes jointed with cement mortar practically form a rigid structure, which under certain conditions may prove unsatisfactory. The author was recently engaged in supervising, on behalf of a firm of contractors, the repairs necessary to a system of sewers constructed in the Thames valley, where many failures due to this form of joint came under his notice.

It was discovered when the sewers were completed and before any connection was made with the houses that the quantity of

subsoil water finding its way into the sewers was greater than might reasonably be expected, and, as the sewage had to be pumped, it was thought advisable to reduce the leakage. The ground through which the sewer pipes were laid was principally gravel and sand, and for the greater part below the level of the subsoil water. Pumping was consequently frequently necessary in carrying out the works.

Two kinds of joints were used, namely, Hassall's patent double lined joint and the ordinary joint made by forcing two strands of tarred gasketting into the joint of the pipe all round, then filling the annular space with cement mortar and finishing off with a well splayed fillet of neat cement, the whole to be then surrounded with well kneaded clay.

From the above specifications of the ordinary joint it would appear to possess all the ordinary requirements for reasonable water-tightness, and if made in dry ground should give satisfactory results. The difficulty, however, with the average workman is that the mortar is often used of such a consistency that when the fillet of cement is placed on the under side of the joint it will not remain there unless immediately supported by the clay to be put around the joint.

The author has in many cases known the fillet on the under side of the joint to fall off before the cement has set, and in other cases there has been a settling or sagging of the mortar on the lower part of the joint sufficient to admit the blade of a knife up to the yarn between the mortar and the barrel of the pipe.

Many leaky joints were found, the water issuing between the mortar and the barrel of the pipe.

A large hand hole is necessary to place the fillet on the under side of the joint and to receive the clay, and in wet ground it is difficult to keep these holes free from water. They also tend to weaken the foundation of the pipe.

If the ground is of a sandy nature pumping in proximity to the trench requires to be very carefully done in order to prevent settlement of the pipes during the filling of the trench and afterwards. In a considerable number of cases the author has found the greater part of the cement washed out of the lower part of the joint.

An equally good joint can be made without using yarn by simply placing mortar in the lower half of the socket and bedding the spigot end of the next pipe well into it, then finishing off as in the former case. By this means there is more likelihood of the lower half of the joint being solid, and there is also a greater depth of cement mortar. Water, however, should be kept away from the outside and inside of the pipe until the cement has set. This kind of joint was substituted for the joint with the yarn in many cases in the works referred to. Great care is necessary to prevent any movement of the pipe during the setting of the cement mortar, such as might occur from unequal bedding and fixing the following pipe in position, etc.

It has been observed in many cases that the fillet on the top of the joint has parted from the socket as much as an eighth of an

inch, preserving the impression produced by being in contact with the face of the socket, and thus showing that the disturbance occurred while the cement was still plastic.

Junctions for future house connections are usually sealed with earthenware disc bedded in and covered with puddle.

Where the sewer is at considerable depth below the surface of the ground, a pipe shaft is frequently brought up vertically in the trench from the junction, and the disc clayed in the socket of the top pipe. If this pipe is brought above the level of the subsoil water no leakage, of course, can take place past the disc, but where the subsoil water is constantly over the disc, or, what is as bad, alternately over and under it (according to the seasons), then these discs are often a source of leakage, the water finding a passage between the clay and the sides of the pipe. Where the sewage has to be pumped and the junctions are sealed in this manner there is no provision for the escape of air when pumping ceases and the consequence is that the water rising in the vertical pipes and compressing the air disturbs the disc, or the air forces its way through between the clay and the socket of the pipe, and thus often starts a leakage. In one case, where some excavators were sinking down for the purpose of stopping a leak, they were considerably startled by the sand and water blowing up in their faces. It appeared afterwards that they had reached to within about twelve inches of the disc set in a vertical pipe brought up from the sewer, and as the engine at the outfall had temporarily ceased working some time before this occurrence, the water had risen up the vertical branch and the blowing up of the sand and water was evidently caused by air pressure beneath the dislocated disc.

On the works previously referred to several leaks were found at junctions sealed in this manner. It was difficult to say to what extent these leaks may have been due to imperfect workmanship in inserting the discs and insufficiently puddling about them, because a continual flow of water washes the clay away.

From numerous gaugings made by the author of the leakage from various sewers where the ordinary joints have been used in water-logged strata, there appears to be some difficulty in obtaining satisfactory results as regards water-tightness.

Of course all the sewers did not leak at the same rate. In some cases there was a greater head of water than in others, and the nature of the defects also affected the amount of leakage, but reducing the results to a head of one foot, the average from a number of comparable examples equaled about 2,000 gallons an hour per mile of sewer. This leakage was not entirely confined to the jointing, but was partly assisted by other defects, to be referred to hereafter.

It is not always an easy matter to localize a leak in a small sewer. The usual method is to pass lighted candles or lamps up the pipes from the nearest manhole, the observer being partly inverted and observing the passage of the light along the sewer. If the leak is in

the upper half of the pipe it will be readily seen if the distance from the manhole is not too great, or, if lighted candles are used, it may discover itself by the falling water putting out the light.

In a 9-inch pipe it was found difficult to see anything except the light at a distance of about 100 feet, while in pipes of greater diameter less difficulty was experienced.

Where the position of the leaks could not be found by illuminating the sewer a convenient mode was to draw a double tight-fitting disc, lined with india rubber, through the sewer and by listening at the manhole the noise made by the falling water, in the case of a leak in the upper half of the pipes, could be shut out or heard at will and the position of it defined to a nicety.

When the leak was in the lower portion of the sewer there was more difficulty, the lights after a certain distance being of little use.

By drawing the disc through the lower end of the sewer and pausing at frequent intervals and watching at the manhole for any flow that appeared the position of the leaks could at times be fairly accurately indicated.

There are other causes of failure in sewer pipes apart from those previously noted, such as subsidence, or lateral pressure through careless drawing of the timber at the sides of the trench in bad ground, or to sudden settlement of the filling over the pipes, such as sometimes occurs when a water pipe bursts near the trench and the filling has not been well rammed.

These causes affect patent as well as the ordinary jointed pipes, although the self-fitting joint of Doulton's is supposed to suffer less from these causes than others.

Should the settlement or movement of the ground occur while the cement is plastic the result is generally a disturbance of the joint, which will probably lead to leakage. If the cement has had time to set hard before the subsidence, lateral pressure, or settlement take place, the result will be a fractured joint or pipe, probably both.

It requires careful pumping where the ground is of a sandy nature and greatly charged with water to prevent disturbing the bed for the pipes to such an extent as to render the foundation insecure, and this is especially so close to a sump hole.

It is difficult to prevent the withdrawal of the finer particles of sand, and as the sewer is being laid uphill from the sump there is a tendency for the water to flow along the trench under the pipes for some part of its course.

The extent to which this will take place depends largely on the position and depth of the sump hole.

Where patent joints are used that can be made with the water running through them, such as Hassall's joint for example, there is no necessity for a very deep sump hole.

To build a manhole with its foundations below the level of the sewer pipes may necessitate having a fairly deep sump hole and drawing the water from under the pipes to some extent seems unavoidable.

A length of pipes jointed with cement mortar in the manner previously described, after the cement has thoroughly set, would be practically inelastic. This want of elasticity was admirably illustrated in some experiments carried out by the author, under the directions of Mr. G. F. Deacon, M. Inst. C. E., who has kindly placed the information at the author's disposal for the purpose of this paper. Four of Hassall's patent double-lined jointed pipes of 15 inches diameter were put together and jointed in the manner usually adopted for these pipes.

They were supported on permanent pillars 8 feet 4 inches apart and temporarily supported between the pillars on sacks filled with sand. The test was applied forty-two days after the pipes were joined, when the cement was set hard. Two saddle pieces of wood were placed on the pipes, one on each side of the joint, midway between the pillars, 8 feet 4 inches apart, and on these saddles was placed the loading platform. An arrangement was made with a light lever by which the deflection was magnified four times and marked on a piece of smoked glass. The glass was swung very slowly in a vertical plane, perpendicularly to and nearly level with the axis of the pipes, from a long radius, a pointer swinging in a loose carriage at one end of the lever, being just in contact with the glass, recorded any motion of the lever, with practically no friction. A zero line was marked on the glass before applying any weight to the pipes. Then, with the glass moving slowly, the sacks of sand were emptied, leaving the pipes entirely supported by the two pillars 8 feet 4 inches apart.

The load was applied gradually until the pipes broke at 21.74 cwt., adding half the weight of the pipes, the approximate load near the center would be 24.91 cwt. The curve drawn by pointer on the smoked glass showed a gradual deflection throughout the time the load was being applied, the maximum deflection just before the pipe broke being 0.142 of an inch, which, divided by 4, would equal 0.035 of an inch, or one-thirtieth of an inch for the actual deflection.

Four ordinary pipes jointed with yarn and cement mortar were treated in a similar manner, the only difference being that the supports were 8 feet 6 inches apart, instead of 8 feet 4 inches, as in the case of Hassall's pipes. The load applied up to the time of breaking was 18.84 cwt; with half the weight of the pipes added, the total load near the center of the pipes would be 21.55 cwt.

The deflection was very slightly greater than in the former case, being 0.15 of an inch, which, divided by 4, equaled 0.0375 of an inch as the actual deflection.

The socket of the pipe at the center was broken away in the lower half, * * * and there was a slight longitudinal crack through the socket, and half way along the barrel of the next pipe on the upstream side, the crack extending through the cement joint. * * * The fractures, however, were confined to the one pipe in this case. which also broke through the socket as well as the barrel of the pipe.

An example of the danger of pumping in proximity to completed sewers is shown in figure 1, plate I. Certain leaks had been observed in some of Hassall's pipes about twenty to thirty feet on the upper side of a manhole adjoining the site of a sump, where there had been considerable pumping during the construction of the sewers.

A trench was sunk over the leaks, the pump being placed just off the line of trench, as shown by the dotted lines.

The leaks having been repaired and the pipes surrounded with concrete, the trench was filled in.

A month after this work was completed fresh leaks were observed, but nearer the manhole, and another trench was sunk some time after adjoining the trench above referred to.

On reaching the sewer it was found that the first pipe past the concrete of the former repairs was badly cracked, the socket of the next pipe was completely severed transversely and the socket of the third pipe from the concrete badly cracked transversely. The pipe nearest to the concrete was found to be the lowest.

No doubt the pumping at the first trench affected the foundation of the pipe adjoining. The pipes in this case were twenty feet below the surface, bedded in sand and gravel, and the average standing level of the subsoil water was about nine feet above the pipes. The forces at work must have been considerable to sever a 15 inch pipe in the manner shown and the author was at first inclined to attribute the fractures to a general settlement of the mass of concrete around the adjoining pipes, but subsequent investigation revealed no fracture or leak in the other side of the concrete, which it would be natural to expect had the concrete settled en masse.

Another example of the effects of pumping is shown in figure 2, plate I.

To complete the manhole shown on the left of the drawing a sump hole was sunk adjoining it to a lower level than the horizontal pipes, which were connected to the manhole by a ramp surrounded with concrete. There was some pumping done there, and subsequently, when the pipes were examined, they were found to have subsided close to the concrete. The first and second pipes past the concrete were completely disjointed and had dropped, the joints being broken. The fourth pipe, a junction, was broken through between the socket and the junction arm, and the next pipe was cracked through the socket.

It will be observed from the drawing that to construct the manhole in the position shown it would be almost impossible in wet ground, with the means ordinarily adopted in sewerage works, to avoid drawing the water from below the adjacent sewer pipes.

The ground on which the pipes were laid in this case was sand and gravel, the water level varying with the rise and fall of the tide.

An example of fractures probably due to subsidence is shown in figure 3, plate I. In this case there were thirteen pipes exposed, the first pipe shown on the left side of the drawing being within

Journal of the Western Society of Engineers,
Vol. 1, No. 4. Plate I.

PARKIN— FAILURES IN SEWER PIPES

Fig 1

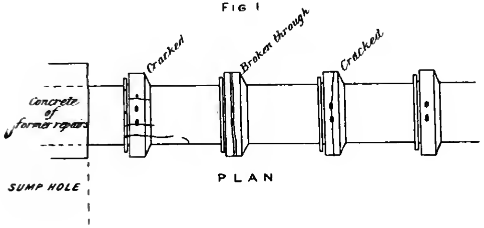


Fig 2

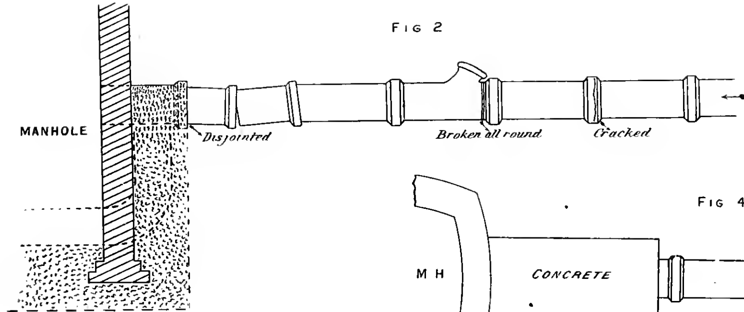


Fig 4

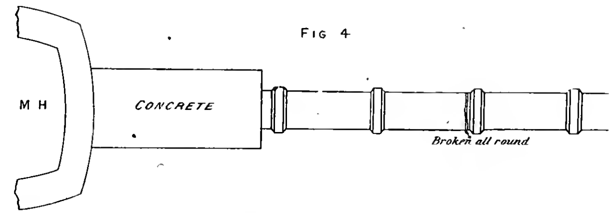


Fig 10

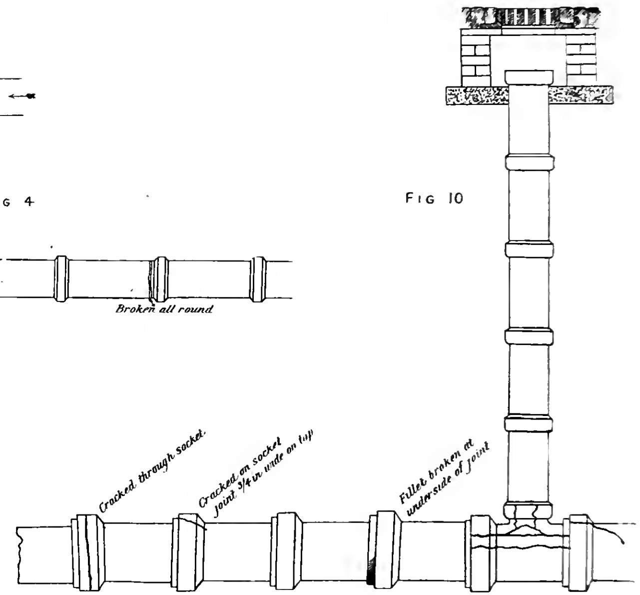
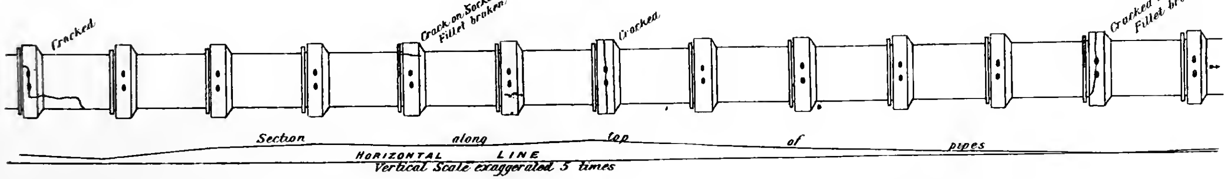


Fig 3



George Reed & Co Lithographers 64 Stanley Street Liverpool

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twenty feet of a manhole, where extensive pumping had been going on during the progress of the works, and where the pipes adjoining the manhole on three sides had fractured.

It will be noticed on comparing the fractures shown in figure 1 and figure 3 that they are very similar, although in the latter case they were not so severe.

Without having the exact levels of the pipes as originally laid it is not advisable to attach too much importance to levels taken after the fractures have appeared, but, assuming these pipes to have been laid with reasonable care and attention to gradient, the levels taken subsequent to the fractures appearing, show a decided depression in the pipes from their original line. The first pipe shown on the left side of the drawing, which should have been the highest, was found to be lower than the pipe seventeen feet away on the down stream side, and the levels of the other pipes clearly indicate some disturbance, which would account for the fractures appearing.

These pipes were about twenty-two feet below the surface of the road, the foundation being sand and gravel, the standing water level being about twelve feet above the pipe.

Many defects were found in pipes in the neighborhood of manholes.

The manholes were on concrete foundations and concrete extended along the sewer pipes for a length of four feet.

In figure 4, plate I, is shown an example of a fracture found in a pipe about five feet away from the manhole concrete. The fracture was transverse, the pipe being completely severed at the back of the socket. It must be borne in mind that the laying of the pipes in practically every case preceded the construction of the manhole.

One cause that might be suggested for this fracture is the settlement of the manhole and the concrete adjoining, although no serious leakage appeared in the pipes connected with the manhole on the other side of it. These pipes, however, were not exposed, and it is not impossible that some joint may have been fractured without developing any great amount of leakage.

The subsidence or movement in this instance must have been very slight, as it was difficult to say from an inspection of the fracture on which side the movement had been.

The jointing material appeared intact, and rather suggests the idea that the pipe had been resting on the socket—i. e., on the assumption that the manhole had subsided.

Another example of a fracture found close to a manhole is shown in figure 5, plate II. The socket of a patent pipe near the concrete was found broken, a large piece of the socket being displaced.

The fracture differs greatly in appearance from those shown in some of the previous examples, but may have been due to similar causes. Many similar cases to those previously described, of defects adjacent to manholes, have come under the author's notice. Fractures, however, were not confined to pipes in the neighborhood

of manholes. They were frequently found some distance away, and probably unaffected in any way by the manhole foundations. In one place, where a length of 160 feet of sewer was exposed, the author found fractures in the pipes at 7 feet, 32 feet 6 inches, 47 feet 6 inches, 75 feet, 80 feet, 95 feet, 97 feet 6 inches, 121 feet, 154 feet, 156 feet 6 inches, and 164 feet from the center of a manhole.

The cracks in all these cases were longitudinal and generally extended through the cement fillet as well as the pipe.

The examples already referred to relate to a few of the cases of fracture caused, according to the author's opinion, principally by vertical displacement.

Many other defects may be attributed to the effects of lateral pressure. In one instance the author found several Hassall's patent jointed pipes had been deflected laterally, probably owing to a slip at the side of the trench when the timber was withdrawn. The maximum horizontal deflection was about three-quarters of an inch in a length of 12 feet 6 inches. As this deflection had undoubtedly taken place while the cement was plastic no fracture was discovered in the pipes, but considerable leakage appeared on the convex side of the joints. With one exception this is the only case within the author's experience where any leakage has occurred through the joints of these patent pipes, although in different places he has seen exposed and tested between 200 and 300.

The effects of lateral pressure are more clearly seen in the case of pipes brought up vertically from the main sewer, such as ventilators or lampholes, or house connections.

Lateral pressure may occur from unequal filling or carelessness in withdrawing the timber from the sides of the trench, or settlement of the filling towards the open end of the trench.

Figure 6, plate I, represents the condition in which a vertical branch for a house connection was found about two years after it was placed in position.

The vertical pipes had gone much out of line, the fourth pipe and the bend both being badly broken.

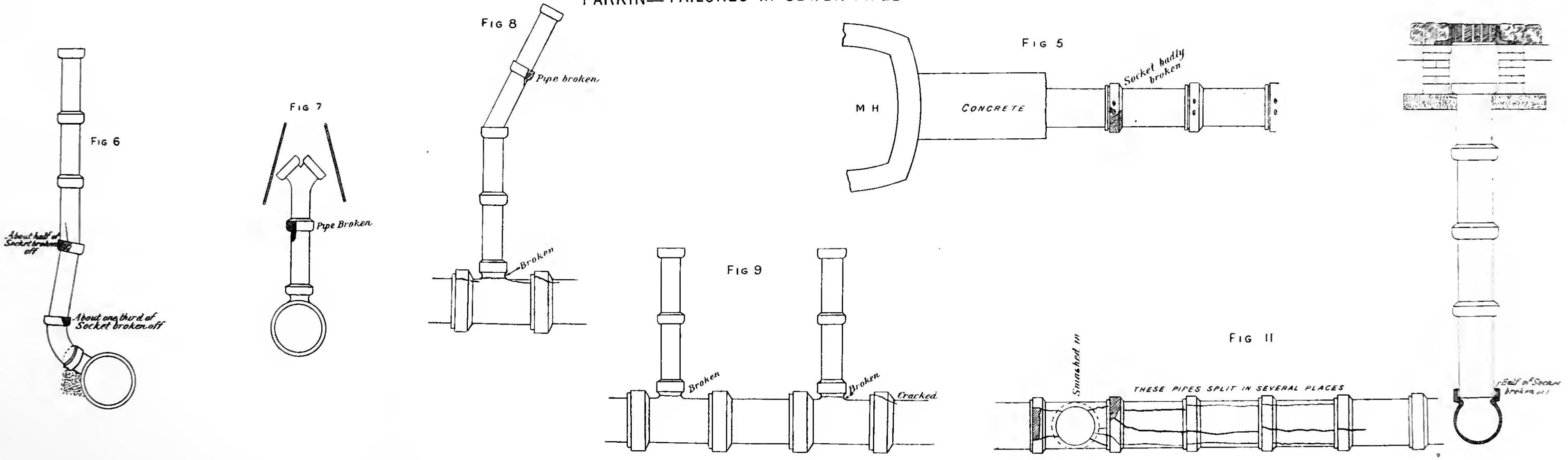
There is little doubt that these pipes had been disturbed by the side of the trench coming in.

Figure 7, plate II, is another instance of lateral pressure. Some poling boards that had been left in the trench indicated very clearly what had taken place, which sufficiently accounted for the broken pipe. There must have been a considerable break of the ground inwards towards the center of the trench.

As previously stated, the manholes were generally constructed after the sewer pipes on each side were laid and it is not improbable that the filling in the trench would settle towards the space left for the manhole.

In figure 8, plate II, defects are shown that may be accounted for on that assumption. The joints of the vertical pipes in this case appeared to have been made first with plastic (the material used with Hassall's patent joints) and finished with a cement fillet.

PARKIN— FAILURES IN SEWER PIPES



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The socket of the third pipe down was badly broken and the pipe nearly disjointed from the fourth pipe, the fourth and fifth pipes were intact, the socket of the upright junction arm was broken around the neck, and both the junction sewer pipe and the pipe adjoining on the lower side were badly cracked. Owing to the plastic being in the vertical joints instead of cement mortar, the branch pipes had been deflected considerably above the third joint without breaking.

Another example is shown in figure 9, where two upright branches for house connections at 4 feet and 9 feet respectively from the side of a manhole, were found broken off from the main sewer just at the necks of the junctions. The sewer pipe adjoining the junction at 9 feet was also cracked through the socket.

It will be noted that the connections just referred to enter the sewer at the crown and at right angles to the direction of flow.

This is not the method usually adopted for connecting house drains with a main sewer, and, perhaps, as a matter of hydraulics, is hardly desirable, but this form of connection was confined principally to positions where the flow of sewage through the branches would be insignificant compared with the volume of sewage running through the main sewer.

Lampholes or ventilating shafts, constructed with pipes brought up vertically from the main sewer to the surface of the roadway, are subject to similar forces to those acting on the vertical branches for house connections.

Generally, when the filling around the pipes has practically done settling, a small brickwork chamber is built around the top pipe, and in the cases to be referred to, on a concrete foundation which surrounds the pipe and is in contact with it.

The chamber is covered with a ventilating grating.

Assuming the concrete to have set tightly around the pipe, and should the filled-in ground settle any further, the weight of the chamber casting, and a portion of any passing traffic over the ventilator, and the weight of the vertical pipes, would be borne on the socket of the junction in the main sewer.

One example of a lamphole that came under the author's notice is shown in figure 10, plate I. It was found on exposing the pipes, which had been laid about eighteen months, that the lamphole junction pipe was completely shattered, the pipe on the lower side badly cracked, and pipes at 7 feet 6 inches and 10 feet on the up-stream side of the lamphole also cracked.

There was little doubt that the lamphole pipes had subsided.

The sewer pipes in this case were about seventeen feet below the surface of the road.

Figure 11, plate II, is a representation of some fractures at another lamphole where the sewer pipes were about twelve feet from the surface. As in the previous case, the lamphole junction pipe was found shattered, and the first three pipes on the lower side split in several places longitudinally, and there were further fractures

in the neighborhood of this lamphole. The ground under the sewer in this case was a very sandy gravel.

Other examples of defects in lampholes and junction pipes in different places have come within the author's experience, but those already described in this paper can be taken as typical cases.

With respect to the chamber constructed around the lamphole pipe at the surface of the roadway, there appears to be no reason why the arrangement should not be made telescopic, by leaving a large open joint between the materials of which the chamber is constructed and the vertical pipes.

In connection with the scheme of Mr. John T. Wood, M. Inst. C. E., for sewering Cambridge, where this method has been adopted, the author has seen the brickwork chamber sink with the settlement of the ground as much as six inches from its original position without in any way coming in contact with, or injuring, the lamphole shaft.

The design as shown in the different sketches referred to in these notes may be open to criticism on some points, but it should be borne in mind that a great number of junctions, sewer pipes and lampholes so constructed are, as far as the author is aware, intact, and fairly answer the purpose for which they were intended.

Many of the fractures in the horizontal pipes were not of a serious character, and if they became no worse would not interfere with the working of the sewer. Of course, they would admit some quantity of subsoil water, and it depends largely on the nature of the scheme what quantity should be allowed to enter the sewers.

Some engineers limit the amount to about one cubic foot per mile per minute, this rate to be proportionate for any length of sewer.

It is useful to have some such standard to work to, although the precautions taken to prevent fractures in the sewer and the form of joint used in wet ground would govern the result very largely. No doubt a liberal use of concrete would have prevented many of the fractures described in this paper.

Careful manipulation is required in introducing concrete under sewer pipes in bad ground.

The water must be got rid of without taking the cement with it, and subpipes through the concrete are liable to get choked and the full benefit of the concrete is not always obtained.

There are defects apart from the question of leakage, such as occur in the manufacture of the pipes, but in most cases these can be noted before the pipes are placed in position in the trench.

DISCUSSION.

Mr. Frank E. Priest said: I see many things in the paper that will no doubt call for some discussion, and there are some points upon which I should like to make a few remarks. Undoubtedly many of the difficulties which the author has pointed out have been difficulties which some of us will think might have been foreseen,

and I fancy from some of the author's remarks that he may have foreseen them himself.

There are certainly some methods adopted which are not common, I hope, in nowaday practice, more especially—treating the end of the paper first—this arrangement whereby vertical pipes are brought directly on to the top of the sewer. I think it must be apparent to everyone—those who have experienced the difficulties of sewer laying and maintenance, and those who have not—that the arrangement shown must be bad and placing around it a heap of concrete really does not do much good and possibly does a good deal of harm.

The method for house connections is very little better, as shown where the pipe comes in on the side and not on the top, as in the other case, because disaster by fracture in the branch is almost certain in that case, but more particularly I would refer to the same arrangement used for the purpose of getting lampholes into the sewer. The weight there, of course, is not only augmented by the settling ground attaching itself to the pipe and hanging on the sockets, but there is a much greater weight which is liable to be brought upon the sewer from the traffic and conveyed directly down so long as the joints are rigid. No doubt a telescopic joint will obviate this, perhaps wholly, but it seems to me that in that case there will be another evil introduced, and that is, that the lamphole in times of storm receives considerable water from the surface. The water will not go directly down the pipe into the sewer, but will, in the first instance, fill up the chamber, at any rate around the top of the pipe. That being practically an open joint, unless there is some arrangement of which I do not know the detail, that water will then get under the base of the chamber, and will cause some difficulty to arise, such as settlement of the chamber or of the road surface, and probably the disturbance of the vertical pipe.

It seems to me that these difficulties need not be called into existence at all, because it is not an expensive matter—and there is no other reason against it that I know—to build a lamphole in brick up from the sewer. By doing this you take off the whole weight from the pipes and put it upon the proper foundation.

Another point of the paper which seems one that should be made much of, is the peculiar manner in which the manholes seem to have been built; when I say peculiar I do not mean peculiar by being unusual, but peculiar to the mind of contractors. There is something in the mind of a contractor which always makes him wish to lay his pipes before making his manholes. It is almost impossible to get your manholes ready to receive the pipes when the time comes to connect them. Of course with such manholes as there are on these drawings, where the pipes are some feet above the floor, when you sink a hole below the pipe in wet ground the material which at first supported the pipe is certain to settle and allow the pipes to settle also, and a result, as we have seen in many of these failures, seems to me to be inevitable.

There was another point that struck me in the paper, and that was, one of the difficulties which arose in these pipes through stopping the pumping, and I suppose, from the results, that the sewer was acting as a reservoir for the collected sewage. Now I know quite well that this is done at times, but it is a most improper practice, because whether the pressure manifests itself upon the tops of the junction pipes or not, it must have a very disastrous effect. Suppose the stoppers had been taken out and the pipes had been connected with houses, there would have been air in these pipes which must have been forced somewhere, and it is natural to suppose that it would find its way to the houses. But even if that had not happened by reason of the house connections being laid in a proper manner, as sometimes they are, something must have gone, because if you have a long house connection you have a great quantity of air in that connection when the sewer is empty, and then, as the sewer fills up, that air is compressed until something gives way and causes troubles almost as great as the author had to remedy in this case.

Another point with regard to the stoppers. It seems that they were only held in position with clay. Anyone who has had experience of clay used for jointing in pipes must know that it is an unsuitable material for a sewer in any position. It is not necessary that it should be allowed to stand alone for keeping stoppers in their places. I have always myself had them held in, in the first instance, by clay being placed round the joint and over the stopper and then the whole cemented in, so that the clay is not exposed to the influence of water, and thus you get a joint which will resist an ordinary amount of rough usage such as you may expect in such places and one which can be broken when necessary without injury to the pipe.

Another feature in the paper was that which deals with the relative flexibility in pipe lines laid under different methods. Well, of course, that is a question which is worthy of a great deal of consideration, but it seems to me to be almost a backward movement to depend too much upon the flexibility of a jointed line of pipes, because, although you may save your pipes from fracture, and you may save your joints from fracture, still it is not an unqualified advantage to have a pipe line which runs up and down hill with freedom. I know that it is claimed as a feature rather to be commended in some pipes that this may take place, but,I myself think that I would almost as soon have a broken sewer as such a line of sewer as that. A sewer which has a considerable deflection is bound to choke unless the conditions are very favorable to it. Such sewers as one has to deal with in practice would choke certainly.

I was led to say in the beginning of my remarks that I concluded the author in reading this paper was free from any of the difficulties which would attach had he been responsible for many of the failures mentioned. My reason for this will be found in his

humorous remark that "without having the exact levels of the pipes as originally laid it is not advisable to attach too much importance to levels taken after the fractures have appeared." The full meaning of those words will perhaps be understood only by those accustomed to the supervision of sewerage works.

I do not think that I have any other remarks to make about the paper. It is not everyone who will give us a paper on failures, and yet they are the most valuable papers that can be given to a society. It is absolutely worthless to have only glossy pictures of the success of works which have not been tried and found out.

Mr. Coard S. Pain said: I fully endorse most of the remarks which the previous speaker has made, and I think it is a very fortunate thing that we have an opportunity of seeing matters unearthed which are generally hidden. I feel quite sure that this is the way to learn, and I have been thinking, while the author was reading the paper, that the man who laid these drains perhaps was not working under the most advantageous circumstances. We do not know what was in the specification or what he was told to do, but presumably there were considerable difficulties. There seems to have been a large amount of jerry work, as far as I can judge from some of the diagrams, because whether it was done afterwards by the people who put in the house connections or whether it was part of the original scheme, it was not satisfactory.

The paper has also opened our eyes to the extreme difficulties met with, and I was rather struck with the previous speaker's remarks as to how he would get over the difficulty with regard to the lampholes—how by constructing a brick chamber he would get over the vertical pressure from the traffic above.

The telescopic arrangement shown on the diagram is one which I have used in similar cases for a long time, with the exception of the concrete at the base of the vertical shaft.

It is most important that a sewer should be watertight. If there is ground water to be dealt with and the ground is porous it will go through the ground. If the ground is not porous, and only a certain amount is admitted to the sewer, the remainder will run down by the side of the sewer, and it might just as well do this at first as at last. I think the joints should be absolutely watertight.

I do not know what the usual practice may be in such cases in the part of the country where this work was done, but it occurs to me that these disasters could not have occurred if the pipes had been tested after they were laid. I should like to ask whether the trenches were kept open until these lengths of drain were finished and tested in any way, or whether they were just opened and covered up as they went along, because that is exactly the result one would expect to find when the trenches are just opened and then filled up again, in a way which I believe is not disadvantageous to the contractor.

I quite agree with the author as to using cement only in joints without any clay. Of course, there is always the difficulty that

unless you get careful workmanship you get the cement coming in and forming obstruction. The amount of supervision which is necessary for this underground work is something appalling. Few are prepared to pay for it, it is absolutely hidden and very expensive, and I can only say that if you have a contractor who is not quite the thing, it is the most difficult matter in the world to keep pace with him and see that he does not get the better of you.

With reference to the flexible joint, I should very much like to hear the experience of Mr. Parkin and other gentlemen who have used these joints. It always seemed to me that, although you may get a flexible joint which may have some advantage, you have the smallest possible contact which it is possible to get. You have the very weakest joint, in one sense, that is possible, and the chance of failure on that account must be therefore greater.

I was struck with the tests, which show that Hassall's pipes stood a much greater weight than ordinary pipes. I should very much like to know if those pipes were tested hydraulically in the first instance before they were put together.

I am very much obliged to the author for bringing this paper before the society.

Mr. John A. Brodie said: Before touching on some of the other points I would like to say that I think it is usual nowadays to put concrete around about the junction pipe at the bottom of a ventilator or vertical junction such as that shown on Fig. 10, Plate I, so as to reduce the pressure upon the junction, as otherwise it is faulty in design and there is a tendency to split the pipe. Water getting down alongside the pipe has also been referred to. I take it that the design shown is for a ventilator only and is not intended to take any water, as it is a very bad arrangement indeed where water is expected to enter through the grating.

I think the paper has certainly shown clearly what most people who are connected with sewerage works know pretty well, that there is still a good opening for a completely satisfactory sewer-pipe joint. A great many joints have been patented from time to time, and some of them are satisfactory under certain conditions, but it seems difficult, even at the present time, to get a joint which is quite satisfactory in bad ground, though the Hassall joint is recognized as a very good joint where you can do with rigid work, while the Doulton self-adjusting joint gives good results where the ground is of a yielding nature. It would be interesting to know whether the author considers the Hassall joint is a satisfactory or fairly satisfactory joint in yielding ground. I would also like to hear from the author what class of ground the samples of cracked pipe lines have been taken from. I presume it has been a very bad, soft ground, and that there has been a considerable quantity of water as well.

It would be interesting to know what quantity of water found its way into a length of this type of sewer, and if the sewers have been removed and replaced by a more satisfactory form, also how much

the leakage into the sewers has been reduced since the pipes were relaid.'

It is pretty plain, I think, that if in waterlogged ground the quantity of water finding its way into these sewers has been very considerable, and one does not wonder that these portions have been opened up, more particularly if the sewage had to be pumped.

As an engineer with a mechanical training, I was naturally interested in the manufacture of pipes of the ordinary description, and I have, therefore, gone through several works where pipes are constructed. I was very much astonished to find the comparatively rough and ready way in which the pipes are first molded and afterwards treated until they leave the works. It seemed to me that though occasionally cast-iron pipe makers give a pretty rough finish to their work they must give place to earthenware pipemakers. Most of us know that it is exceedingly difficult to get anything like a decently straight pipe for sewer work, even when paying high prices, and I was under the impression that it was the fault of the pipe material at one time, but I am not now quite sure that the fault should be very largely shifted to the shoulders of the makers and managers of the pipe works.

Mr. Henry H. West said: I should like to ask a question. It is a matter that I am not at all familiar with, and my knowledge on the subject is absolutely nil. It appears to me, however, that these vertical pipes may have failed from two causes; one has already been spoken of, the superincumbent weight of a long length of pipe from the sewer to the surface; the other, from imperfect filling in of the shaft in which the vertical pipe is fixed, and there again it would probably be failure from the superincumbent weight. It strikes me that if we had a long length of iron pipe to deal with we should not let the weight of that be carried by the jointed length of pipe into which it ran.

It has passed through my mind that something might be done in the way of a bracket on this bottom length of pipe to spread the weight and let it come past the main sewer pipe into which it is socketed. While Mr. Brodie was speaking (I think some remark that he made suggested it), it occurred to me that if these pipes were made taper, there might be a mass of concrete here, of any size you like, that would spread the weight and keep it off the socket of the pipe itself.

I do not know that it is a feasible thing to do, but it occurred to me as being possible.

Mr. T. Duncanson said: I have very great pleasure indeed in proposing a vote of thanks to Mr. Parkin for his very interesting paper. Looking the whole question over, it seems to me that it has been a case where the engineer has had a greater regard for economy than for good work, and that, possibly, had a third of the money spent on repairs been spent in putting a concrete foundation under and concrete round these pipes, the work might have been satisfactory and substantial now. I notice in the paper the

author mentions that 2,000 gallons per hour per mile is the amount of leakage under one foot of head. Does that mean that if there were nine feet of head you would get three times that quantity? (Mr. Parkin: "Yes.") I agree with all the other speakers. I think, with regard to the manhole, if you have a good concrete base that ought to be quite sufficient and substantial, and a brick manhole would not be necessary.

Mr. J. A. Crowther said: I have much pleasure in seconding the vote of thanks. I think it is a very good thing that we, who have something to do with the laying and management of these sewers, should know what is under the ground.

With regard to the ventilator or lamphole shown on the diagram, I have put a good many in. In the bottom I placed a landing (say) six inches thick, with a properly radiated bottom and brick sides about nine inches thick. I consider the design on the diagram is only a makeshift. It is a very difficult matter to keep the pipes in a vertical position. I prefer to put a brick chamber in from top to bottom.

Mr. John H. Parkin, in reply, said: I agree generally with what Mr. Priest has said. I think, however, that in the case of lampholes there is no necessity to construct them in brickwork; as with a concrete base under the horizontal pipes and a column of concrete brought up around the vertical pipes, they would remain intact. I should also say that there are a great many cases in my experience, of lampholes constructed with pipes in the ordinary manner and with no other support than the ground, which have developed no defects.

As to laying pipes before the manholes are constructed, it is perhaps not a very satisfactory proceeding, but it is very generally done. To commence laying from a manhole is quite correct, but to join onto a manhole already constructed, would, in most cases, lead to having a butt joint in the sewer, and might be inconvenient in many ways. To wait until a manhole was partly erected before proceeding with the pipe laying would be leaving the work too much to the mercy of a bricklayer, which is not always desirable and might lead to considerable delay at times.

In most pumping stations it is difficult to prevent stopping the pumps occasionally, but where there is a deep tank sewer and the water does not rise up to the house connections, an occasional stoppage of the pumps does no great harm.

As to jointing the discs fixed in the junction arms, I agree that clay under certain conditions would not be very satisfactory. A thin slate disc cemented in might answer fairly well under most conditions.

Mr. Pain suggests that the work could not have been properly inspected as it was being done. That is not altogether correct.

Take the examples shown on figure 1, plate I, for instance. These pipes were quite sound when they were laid, and had developed no defects even twelve months afterwards, and it was not

until the subsidence brought about by the pumping referred to that any fractures were discovered.

I agree with Mr. Pain that there is seldom sufficient inspection in sewerage works. As to the efficiency of Doulton's self-fitting joint, having only seen about one mile laid I cannot say generally as to what extent they form a watertight sewer, but I understand in some cases cement mortar is being added to these joints.

The pipes referred to in the experiments were not tested with hydraulic pressure. They were simply tested for deflection.

I do not see that water entering the ventilator chamber can do any great harm by passing through the open joint between the chamber and the pipe. In an ordinary trench the ventilator pipes would be surrounded by the filled-in material and water coming on the trench would probably find its way down by the back of the chamber just as well as through the grating and the open joint, which would soon be filled with sand, clay, or some non-setting material.

In reply to Mr. Brodie's question as to the nature of the ground these pipes were laid on, it was, as mentioned in the paper, principally composed of sand and gravel. In places it was pure sand, but principally a sandy gravel. The presence of so much water, in some parts as much as thirteen feet above the pipes, and the consequent pumping rendered the ground on which the pipes were bedded rather unsatisfactory.

The Hassall's joint I found very reliable as regards the watertightness of the joint, but a great many of the fractures or cracks found in these pipes were in or about the socket.

As to the total leakage in the system of sewers, it varied from 23,000 gallons per mile per twenty-four hours in the summer to 46,000 gallons per mile per twenty-four hours in the winter.

Several thousand pounds were spent in repairing the sewers in places, but without affecting the total leakage to any great extent.

In one case a whole length of sewer was exposed and the joints repointed with cement mortar, and other work done in the way of repairs, yet a few months after it was found to be leaking at the rate of over 100,000 gallons per mile per twenty-four hours.

I agree with Mr. Brodie's remarks about pipe making. Pipes are frequently delivered that are not circular, or square at the ends with the axis of the pipe.

I think the difficulty Mr. West pointed out could have been got over in the way I mentioned, by placing a concrete base under the pipe and bringing a concrete column up the vertical pipes.

The president asked how it was discovered that the sewers were leaking. In this case no sewage had been admitted to the sewers until the examination was made, and of course when this was done it was found that large volumes of water were flowing through the pipes, which could only be due to infiltration through the joints or fractures.

SOME FUEL PROBLEMS.

BY JOSEPH D. WEEKS, PITTSBURG, PA.

(*Trans. of the Am. Inst. of Mining Engineers, Vol. XXV.*)

The primary problems of civilization are material ones; their answers are written in fire. When these problems in their higher aspects have pressed for solution it has been out of the burning bush that the Divine voice has spoken, or in the cloud and smoke that the Divine finger has traced the rules by which these problems shall be solved. It is with the material problems, however, that we, as engineers, have to deal.

It is by fire that these problems are solved. With a marvelous insight into the secrets of power the Greeks made Prometheus, who stole fire from heaven to bestow it upon mortals, the author of civilization. In the words which Aeschylus makes him utter as he lay bound on Caucasus, "All arts among the human race are from Prometheus," and it is from the "bright play of fire that all arts spring." In this myth is thinly veiled the origin of the mechanic arts, and is dimly suggested the part fire has played in their development. The myth also foreshadows the triumph of civilization, by the aid of fire, over the forces of nature, for there shall one day be invented a flame more potent than lightning, before whose power Jupiter himself "should fall dishonored."

On the part that fire has played in civilization we need not long dwell. For most of the centuries—indeed, up to the day when boiling water told its secret of power to Watts—its use was chiefly its primary one to heat and light and not its secondary one as a source of power. Its chemical effect and some of its direct mechanical uses were known, as well as its calorific effects. It cooked the food, but it did not drive the plow nor swing the scythe, nor thresh the grain, nor grind the meal; it smelted the ores, but it did not drive the blast. It heated the iron, but it was the brawny arm of the smith or the force of the falling water that hammered into shape, while even as in Prometheus' time the land was still traversed "with steeds in cars obedient to the rein," and the "canvas winged chariots of the mariner" still roamed over the ocean. In a word, while fire gave heat and light, the sources of power through all these centuries were muscle and wind and falling water.

It is not these primary, but the secondary and even more remote effects of fire that have caused civilization to move with a quicker step. While all the marvelous effects of fire, which have been for ages the possession of humanity, still remain as among its greatest endowments, it is as a source of power that fire in the last hundred years has been of such inestimable value. The beginning of its era of power was Watts' invention of the steam engine, for which the first patent is but 113 years old. The science of thermo-dynamics on the principle of the conservation of energy, one of the most im-

portant advances ever made in scientific knowledge, was created as late as the years 1845 to 1855. Even what we have learned in the centuries just closing as to the power of fire, is as nothing to the stupendous power of this agent that shall yet be revealed.

It is quite needless to say that, as back of this power is heat, and back of the heat, fire, so back of the fire is fuel and that for the civilized world, fuel is but another name for mineral or fossil coal, and that for us the fuel question concerns itself chiefly with the possession, production and uses of coal. There are other fuels than mineral coal, as petroleum and natural gas and the vegetable fuels. Indeed, the fuel question in England at one time, and not many years ago, especially in the iron trade, was a question of charcoal, but for furnishing the world's heat and doing the world's work, none of these other fuels cut any figure except in restricted localities.

There are also other sources of power, as light and wind and water flow, and muscle, and were these as willing, as constant, and as untiring and tractable servants as heat from fuel the power that could be derived from these natural forces is so vast that the problem of power would be solved, but there are night and clouds to stop the work of the light; the wind is fitful, it does not always rain, and the muscle tires; but night and day, in storm or calm, in dry or wet, and at the end of the longest and weariest day, fire from coal will always answer the demand for power. Nor can we yet call into play that limitless power we call "solar energy," of which we know so much, with which now we can do so little. In our present impotence coal is mightier to do our work than even this source of all power. The power problems to-day, then, are fuel problems, and fuel is mineral coal.

The world has a vast store of this mineral fuel—coal. How much no one knows. But, vast as are these stores, the consumption in certain countries has been so great that nations have affrightedly asked to know how long the supplies would last. In England the question was discussed by such authorities as Sir William Armstrong before the British Association, Mr. Jevons in his work on "The Coal Question," and in Parliament by John Stuart Mill and Mr. Gladstone. As the result of these discussions, the alarm over the probable exhaustion, in the not distant future, of its coal supplies was so marked that a royal commission was organized, who, arguing from several premises, estimated the duration of the supply at various periods, from two hundred and seventy-six years to over twelve hundred years. But the consumption of coal in Great Britain has increased at a rate much in excess of that upon which the lowest estimate of the royal commission was based. In 1780, about the time the steam engine was invented, it was some 6,500,000 gross tons a year. It had arisen to 27,000,000 tons in 1816; to 50,875,000 tons in 1850; to 84,042,698 tons in 1860; to 112,875,525 tons in 1870; to 146,969,469 tons in 1880; to 181,614,288 tons in 1890; and to 188,277,525 gross tons (210,870,828 net tons) in 1894. The result of the discussions on the subject of the duration of the coal supply of Great

Britain was the conclusion that if the output increases in the same ratio as it has for twenty or thirty years the coal will be exhausted in a little over a century. These estimates are now regarded as excessive, as it is conceded that there is in each nation a limit to industrial development which, without considering the great economies in the use of fuel, will also limit the expansion of coal production. M. Gruner places this limit for England at 250,000,000 tons, which supposes a mining population of a million miners and a working population of five millions.

In this country the production of coal has been increasing in a much greater ratio than in Great Britain. We cannot go back to the eighteenth century and give figures of production of coal, nor is that necessary in order to indicate how enormous has been the increase in its production and consumption in the United States. At the tenth census, 1880, the production of coal in the United States is reported at 71,481,570 net tons; at the eleventh census, 1889, it had risen to 141,229,513 net tons, nearly double, and in 1893, according to the report of Mr. E. W. Parker of the United States Geological Survey, it was 182,352,774 net tons, an increase of more than two and one-half times in thirteen years, doubling about every five years.

Similar increases could be shown for the other great coal producing countries, as Belgium, Germany, Austria, France and Russia. The world's demands for heat and power are increasing marvelously, while the world's supply of coal is a definite quantity and it is an evident proposition that with the exhaustion of its coal not only will the power and influence of a nation decline, but even its existence may be imperiled.

The fuel problem, therefore, is not only an industrial one, but a political and politico-economical one of the greatest importance.

As the amount of coal in the earth's strata is a fixed definite quantity, in discussing the fuel problem we cannot proceed on the assumption of an increase in this quantity. We may discover deposits of which now we have no knowledge, but this does not add to the world's coal supply, but only to our knowledge of where that supply is stored. Some coal may still be forming in peat bogs, but the amount so being formed or that will be permitted to develop into coal will hardly be worth considering. It is evident, therefore, that an increase of the actual quantity of coal stored in the earth is not a factor of the fuel problem.

It is possible, as has been suggested, that other sources of power and even of heat, such as chemical action and solar energy, especially the latter, may be, and no doubt will be, largely utilized in the future, but these are questions it is not within my power to discuss, and the day when these and other sources of power will be largely used will be when the supply of coal is very much reduced and its value very much increased.

As, therefore, we can expect no increase in the amount of the world's supply of coal, the fuel problem is to increase the efficiency

of that we have to make each ton of coal that remains in the hill do a much greater amount of work than a ton now does. In a word, the fuel problem is to reduce the waste and increase the efficiency of the coal we possess.

This problem divides itself into three distinct parts—that is, problems connected with:

1. The mining of coal and its preparation for market.
2. The use of coal.
3. The products of coal other than heat.

These problems all concern waste.

First, as to the problems relative to mining the coal and preparing it for market.

It is estimated that as the result of the coal mining of the last fifty years, not more than 30 per cent of the coal remaining in the veins worked has on the average been won and laid down at the point of consumption or use. This loss of 70 per cent does not, of course, include the loss due to geological causes, and especially to erosive agencies that have cut so deeply and so wastefully into the coal originally deposited in the coal fields. So great is this geological waste that Prof. Lesley estimates that not over 1 per cent of the coal originally deposited in the great Pittsburg bed still remains, and yet he declares this bed, robbed as it has been, to be the most valuable deposit of coal in the world. In the later years of this half century the waste has not been so great; but when all things are considered the estimated loss in mining of 70 per cent of the coal remaining in the strata is not excessive.

As to the causes of this waste and the methods by which it may be reduced but little remains to be said, at least so far as relates to anthracite coal in this country, since the publication of the report of the Pennsylvania commissioners on the waste of coal mining, of which commission our old friend and sometime president of this institute, Eckley B. Coxe, was chairman.

Mr. Coxe points out that there are two classes of waste in coal mining:

1. That which is absolutely necessary and cannot be avoided.
2. That which may be diminished or done away with.

The unavoidable waste is defined to be that portion of the coal that must be left in the mine for various purposes. It does not follow, however, that what is to-day termed unavoidable waste is absolutely unavoidable. It may be, with our present knowledge, but what this term "unavoidable waste" really means in many cases is simply that under present conditions, or under the engineering adopted, it is regarded as most economical to leave this coal in the mine. It is left to maintain the workings, the slopes, shafts, gangways, etc., to support the surface, to make the floor and roof, to keep the water from the lower level and save the expense of pumping. In a word, to keep the mine safe and in such condition that it can be worked economically. Conditions, appliances and methods may so change, beyond question will so change, that what

is economical to-day may be most wasteful to-morrow. The history of mining shows this.

Just what is the loss from this so-called unavoidable waste in mining at the present time is difficult to ascertain. In some instances it is not 10 per cent; in others as high as 50 per cent or more. This refers to the veins actually worked and to those portions that are worked and not to those that are in whole or in part regarded as not workable. If this unavoidable waste averaged 20 per cent of the amount of coal produced the loss from this source in the United States in 1893 was 36,470,555 net tons, and on the production of Great Britain in 1894 it was 42,174,166 net tons. If the waste for fifty years was considered the amount would be enormous. This unavoidable waste can be reduced. It is being reduced as the results of the application of engineering skill. When the day comes that the near exhaustion of coal will be a thing of to-morrow, and not of a century, it will be found that a waste that is now called unavoidable will then be termed criminal.

The avoidable waste in mining is largely due to:

1. Miscalculations as to the amount of coal that must be left for the pillars, etc.
2. The leaving of large amounts of coal unmined in a vein.
3. Imperfect work on the part of the miner.

The loss of coal from miscalculations or bad engineering of the mine is enormous. Pillars may be too large and the coal wasted; or too small, and the pillars crush and shut off the coal beyond. It is not unusual to leave unmined a part of a vein that is either under or above a slate, and which may not be quite so pure as that mined. The waste from this source is enormous. There are mines in the Pittsburgh regions where, with $71\frac{1}{2}$ inches of coal, but 32 inches of clean coal and the bearing-in coal of 4 inches are mined; 36 inches out of $71\frac{1}{2}$ inches; the rest is left untouched, a loss of $35\frac{1}{2}$ inches; practically one-half of the coal is left in the mine, besides the waste in mining. This custom is not at all uncommon. The miner may do his work very unskillfully in bringing down the coal, in loading, and other ways to which I need but refer at this time.

As Mr. Coxe so admirably points out in the report above referred to, there is, in connection with the preparation of anthracite, a large amount of loss. This is not so great with bituminous coal, but there are culm and slack heaps about bituminous as well as at anthracite mines. Mr. Coxe estimates that the amount of coal sent to the culm bank in the anthracite region of Pennsylvania since mining began has been 35 per cent of the total production, or, up to the close of 1892, 315,700,000 tons. At certain collieries, from the year 1820 to 1883, 20 per cent more coal went to the dirt banks than was marketed, and it was not unusual for an amount equal to 50 to 75 per cent of total shipments to go to dirt banks.

In view of all these facts the statement that on the average during the last fifty years not more than 30 per cent of the coal in the

measures mined has reached the place of consumption is not at all surprising.

How can this waste be avoided?

It cannot be entirely avoided, but it can be still further decreased by just the methods by which it has already been largely reduced. Mechanical means, instead of the coal itself, can be used for supporting the roof and surface; gobbing up will often give a much larger percentage of coal; better engineering of the collieries will give better methods and less waste. All of the vein can be mined, even if a portion of it is inferior, and many methods can be greatly improved.

Secondly, as to the problems connected with the use of coal.

It is estimated that not to exceed 10 per cent of the possible energy in coal is utilized; indeed, 5 per cent is the amount most frequently named. Some of this loss is unavoidable and will ever be so until we have solved that greatest of all modern industrial problems, how to obtain energy direct from coal.

But much of this waste is avoidable, and to reduce this avoidable waste is the fuel problem in connection with the use of coal.

What has been done in reducing this waste in the last 100 years is simply astonishing, and what is of especial interest is that many of the improvements and processes that have been introduced into the arts within this time have been the results of attempts to diminish this waste of fuel. The story of many of these inventions, could they have been told by a Stevenson, would have given us new Arabian Nights tales more marvelous than those he did tell. What marvels have been performed by the genii Watt unloosed from the boiling kettle! The gas Murdock told men how to use is a veritable Aladdin's lamp, and the stories of the wonders of Neilson's hot blast, and Bessemer's fiery converter, and Siemen's furnace, of the heat-cycle, and many others are marvelous almost beyond belief.

I do not propose to-night to weary you with the details of what has been done in fuel economies in the arts, but to briefly outline these accomplishments merely as an indication of the line on which future problems may be solved.

Fuel in the arts has at least a three-fold use:

1. As a simple heat agent.
2. As an agent of chemical changes.
3. As a source of power, or, better, energy.

We have no complete estimate of the consumption of coal for various purposes in the United States, but the Royal Coal Commission in 1871 and Mr. Price Williams in 1889 made very careful estimates of the distribution of coal consumption for Great Britain. I had hoped to obtain an approximate estimate of the consumption of coal for various purposes in the United States, but so far have failed.

The estimate of the Royal Commission is as follows:

CONSUMPTION OF COAL FOR DIFFERENT PURPOSES IN GREAT BRITAIN.

COAL COMMISSION ESTIMATE, 1871.

Tons of 2,240 Pounds.

Uses—	Tons.
Iron	32,446,606
Power and general manufacturing	25,327,213
Domestic	18,481,527
Gas and water	7,811,980
Mining and collieries	7,225,423
Steam	3,277,562
Railroads	2,027,500
Smelting, other than iron	859,231
Miscellaneous	195,045
	97,652,087

Percentages for Various Uses.

	Per Cent.
Metals and mines	44
Domestic, including gas and water	26
General manufacturing	25
Locomotion by land and sea	5

Consumption of coal for different purposes in Great Britain (Williams' estimate, 1889):

	Per Cent.
Production of steam power, including collieries	30.30
Manufacture of pig iron and metallurgy	17.26
Navigation	8.66
Railways, including fixed engines	3.98
Waterworks and miscellaneous	1.40
Domestic use	17.44
Gas manufacture	5.87
Export	15.09
	100.00

It is impossible at this time to distribute this consumption even approximately into the three uses—heating, chemical and power—but it will be seen readily that by far the larger consumption is for power and in iron manufacture. It would seem from an inspection of these two estimates that from 60 to 70 per cent of the coal consumed is for power, and for iron and steel manufacture.

What economies have been wrought in these industries in the past 100 or 150 years?

In engines since the days of the Newcomen engine the duty of 94 pounds of coal has increased from 7,450,000 foot-pounds to 140,-

000,000 foot-pounds, the highest duty of Mr. Leavitt's pumping engine at Louisville, and the pounds of coal per indicated horse power decreased from 26.6 pounds to 1.33 pounds, an increase in duty of 20 times and a reduction in coal, of course, to one-twentieth.

The following table shows what has been done in detail:

DUTY OF CORNISH ENGINES.

	Duty in foot-pounds per bushel (94 pounds) of coal.	Pounds of coal per 1 h. p. (estimated).
Newcomen	7,000,000	26.6
Smeaton	10,000,000	18.6
Watt, 1800	20,000,000	9.3
Lean's report, 1815	52,300,000	3.6
Lean's report, 1827	67,000,000	2.8
Lean's report, 1834	98,000,000	1.9
Lean's report, 1840	107,000,000	1.7

Highest duty of Mr. Leavitt's pumping engine at Louisville, 140,000,000 per 100 pounds of Pocahontas coal. Pounds of coal per indicated horse power, 1.33.

As to the reduction of waste in iron and steel manufacture: To an audience like this, to show what has been accomplished, I need only mention Nielson's hot-blast, the Bessemer or pneumatic process, the Siemen's regenerator.

One example of the reduction in the use of coal in iron manufacture must suffice. In 1828 Neilson invented the hot-blast, which Mushet said "ranks with the invention of cotton spinning." At the Clyde Iron Works in 1829, for a six months' run, the average coal consumption per ton of pig with cold-blast was 8 tons 1 cwt., 1 qr.; for six months in 1830 at the same furnace, with the same blowing-engine, the consumption with hot blast was 2 tons 5 cwt. 1 qr. To-day we are making pig iron with a ton of coke, or $1\frac{1}{2}$ tons of coal to a ton of pig.

This indicates what has been done in the arts of reducing fuel consumption.

But our modern practice has not reached the limits of economy. If we get but 10 per cent of the available energy out of our coal there must be a vast field for the exercise of engineering skill in reducing this enormous waste of 90 per cent. Sir William Armstrong states that without carrying economy to extreme limits, all the effects now realized from the use of coal could be obtained by an expenditure of half the quantity.

In what direction are we to seek for the answers to the problems connected with the use of coal? I can only briefly indicate them. They are:

1. A more perfect combustion—that is, from the same amount of fuel more heat units must be developed.

2. Improved appliances for saving this heat and transmitting it into energy. Not only must these increased heat units do more

work, but each individual heat unit must directly develop more energy.

3. Recuperation of so-called exhausted energy—that is, the heat must continue at work until the actual limit of exhaustion has been reached.

The use of gases instead of solid fuel is an example of the first direction in which we are to look for the answers to the problems connected with the use of coal. The improvements in the steam engine noted above are examples of the second class and the Siemen's regenerator and compound engines of the third.

Thirdly. The saving of fuel products other than heat.

As has been pointed out, it is as a source of heat and power that fuel—that is, coal—is most useful to the world. But it has been learned that there is locked up in this fuel a marvelous series of products which for their beauty, their wonder, their sweetness, their use, are unexcelled, and the end of the story of these products is not yet.

To indicate what these products are I need but name the brilliant coal tar dyes, such contributions of untold value to the healing art as phenacetin and antipyrine, many of our modern perfumes and essences, and saccharine, sweeter than cane sugar.

While the discovery and character of these products are the fairy tales of science and while the products themselves are of untold value to mankind, there are fuel products other than heat and power and other than these coal tar products that in amount and value far exceed these dyes, and medicines, and perfumes. The chief of these are the tars themselves from which are derived the light and heavy oils, the creosotes, benzoles, the ammonia from which we get that most valuable of all fertilizers, sulphate of ammonia, upon which the exhausted fields of our country must depend for their renewal of power. From the nitrogen of this fuel we may also obtain that most poisonous of drugs and yet that valuable agent in gold extractions, cyanide of potassium.

The amount of these products contained in every ton of coal and the consequent amount that we are every year throwing into the air as waste aggregates an amount almost beyond belief. From every ton of coal coked in the United States it is fair to assume that in any of the by-product coke ovens there can be produced at least 3 per cent of tar worth 1-3 of a cent a pound, 1 per cent of sulphate of ammonia worth 3 cents a pound, $\frac{1}{2}$ of 1 per cent of benzole worth 2 cents a pound, and 1 pound of cyanide of potassium worth 50 cents a pound. As in 1893 14,916,147 tons of coal were coked in the United States, the possible production and value at present prices of these products would have been as follows:

Material.	Amount (pounds).	Value.
Tar	596,645,880	$1,988,820
Sulphate of Ammonia	298,322,940	8,949,688
Benzole	149,161,470	2,983,229
Cyanide of Potassium	14,916,147	7,458,073
		$21,379,810

The above products, however, are only those from the 15,000,000 tons of coal coked in one year. What about the value of the by-products of the 113,000,000 tons of coal not coked? How many tons of tar and ammonia and benzole and cyanide could be saved from this amount of coal? The amount of ammonia would be something enormous, though the tar and benzole, if the coal was properly burned into gas before it was applied to heating purposes as it should be, would not be so great as when the coal is coked. The Mond circular producer, which I saw at work a year ago in England on Yorkshire coal, gave forty-eight kilos (105 pounds) of sulphate of ammonia per ton of coal charged, and eighty to ninety pounds was the regular yield, and all this vast amount of sulphate of ammonia, for which our wornout land all over the United States is crying, is being lost.

Let us recapitulate.

Of the coal still remaining in the seams worked, not more than 30 per cent on the average in the last fifty years has been won, that is, 70 per cent has been lost.

The percentage of the possible energy of coal utilized to-day does not exceed 10 per cent, if, indeed, it reaches 5 per cent.

That is but 10 per cent of the 30 per cent of the coal won in our veins, or but 3 per cent of the possible energy imprisoned in the coal in our hills, is ever released for useful work.

The value of this lost energy must every year, in the United States alone, reach hundreds of millions of dollars.

A low estimate of the value of by-products per ton of coal burned would be 50 cents. This would be $64,000,000 on the bituminous coal mined in 1893. For an age that prates so loudly of its economies, this is a sorry showing.

Is there not in this fuel question a problem that demands most earnest work from our engineers, and in which there is for the miner and manufacturer untold wealth?

"THE CITY AND SOUTH LONDON RAILWAY; WITH SOME REMARKS UPON SUBAQUEOUS TUNNELLING BY SHIELD AND COMPRESSED AIR."

By James Henry Greathead, M. Inst. C. E.

(*Minutes of Proceedings of The Institution of Civil Engineers, Vol. CXXIII. Issued March, 1896.*)

TUNNELLING.

HISTORICAL.—As long ago as 1818, Sir Isambard Brunel took out a patent for "forming tunnels or drifts underground," the main principle of which was the forming of excavations suitable to tunnels of large dimension "by an operation nearly similar to that of forming a small drift." The body or shell of the tunnel, he stated, might be made of brick work or masonry, but he preferred to make

it of cast-iron, and to line it afterwards with brickwork or masonry. In his patent specification two modes of carrying out his system are described and shown, one by means of a number of small cells with friction rollers between them, each forced forward independently by any suitable mechanical aid, but preferably by hydraulic pressure. This method he subsequently employed, without the hydraulic presses, in the construction of the Thames tunnel. In the other method, which he called a teredo, from its "analogy to the Teredo Navalis," he proposed to work spirally upon a small face of excavation nearly at right angles to the main face of the tunnel. It has never been used, and it would appear to be not quite practicable. The drawings show cylindrical tunnels of cast-iron combined with brickwork or masonry, but in the Thames tunnel, commenced seven years later, Brunel adopted a rectangular section, probably as being more suitable for his form of shield; though Mr. Henry Law, in his account of the Thames tunnel,* states that "the strata being horizontal and, from their proximity to the river, subjected to constantly varying pressure, it was considered that a circular structure would have been exposed to very irregular strain." A circular section would certainly have been impossible of achievement with the form of shield actually employed by Brunel. With the abandonment of the circular section, the idea of using cast-iron for the lining of the tunnel became impracticable.

Though a great engineering triumph with the appliances available at the time of its construction, and a lasting testimony to the genius and spirit of Brunel, the mode of construction of the Thames tunnel has not been attempted elsewhere; and there can be no doubt that for nearly half a century that work served as a warning to engineers and capitalists not to embark in any undertaking of a similar character, and no other subaqueous tunnel was constructed. Indeed, so disastrous was that early experience that in 1868, when, an Act having been obtained for the construction of the subway under the Thames at the Tower, it was desired to let the work, no regular contractor could be found to undertake it. The Thames tunnel was commenced in 1825 and was finished in 1842.

TOWER SUBWAY.—So far as the author is aware, no other work of the kind was embarked upon until the little tunnel at the Tower, designed by the late Mr. Peter Barlow, F. R. S., was commenced in 1869. In the construction of this cast-iron tunnel, a cylindrical shield was used, which was forced forward as a whole by six screws, worked by men inside the shield. The tunnel lining, of six feet seven inches clear internal diameter, is composed of rings eighteen inches long, each consisting of three segments and a key-piece, the metal being seven-eighths of an inch thick and the flanges two and one-eighth inches deep. The shield consisted of a

* "A Memoir of the Thames Tunnel," by Henry Law. Weale's Quarterly Papers on Engineering, 1845, Vol. III, and 1846, Vol. V."

cylinder of a single thickness, half inch, of iron plates, made slightly tapered, the larger diameter being at the front end, to reduce the skin-friction of the clay on the outside. At the front end was a cast-iron ring with rounded edge forward, to which was bolted a diaphragm of wrought-iron plates, having a rectangular opening in the middle extending to within a few inches of the top, for the passage of workmen and materials. In rear of the face were fixed the six screws, each two and one-half inches in diameter, abutting against the forward end of the completed tunnel, by which the shield was propelled. The tunnel is 1,350 feet long and in clay throughout, and, with the shafts, was constructed within the year 1869; the maximum speed reached being nine feet per day of twenty-four hours, divided into three eight-hour shifts. The shafts, ten feet in diameter, are respectively about fifty feet and sixty feet deep, and the minimum cover over the tunnel under the river is twenty-two feet of clay. The shafts and tunnel were carried out by the author for the company at a cost of about £10,000. Steam-lifts were subsequently placed in the shafts, and a small carriage, holding twelve persons, and of two feet six inches gauge, was hauled to and fro through the tunnel by a wire rope and a four-horse power steam engine in each shaft. The number of passengers that could be carried in this manner being too limited to pay working expenses, the machinery was soon discarded, and spiral stairs and a footway substituted to enable foot passengers to use the subway.

Following the Tower subway, a short length of experimental tunnel, eight feet in diameter, was, in 1870, constructed in New York for the "Broadway Pneumatic Railway," and another similar short tunnel was afterwards built in Cincinnati. These tunnels were not subaqueous, but shields of boiler plate similar to the Tower subway shield, propelled by small hydraulic presses, were used. A short length of the Cleveland Lake tunnel was subsequently constructed with a shield six and one-half feet in diameter and six feet in length, composed of heavy boiler plates. It was propelled at first by means of screws, and afterwards by hydraulic presses. The tunnel lining was of masonry, and was inserted in sixteen-inch lengths. After 140 feet had been constructed in this way the shield was discarded. It was found impossible to prevent the cracking of the brickwork after each advance of the shield. In the New York and Cincinnati tunnels no attempt appears to have been made to close up the cavities left outside the lining upon the advance of the shield. Tunnelling by shield then fell into disuse in America, so that when, in 1872, Mr. E. S. Chesbrough was preparing plans for the proposed tunnel at Detroit, he, after consideration, rejected the shield as unsuitable, and proceeded to construct the tunnel in brickwork in the ordinary way. The Detroit tunnel was commenced in 1872, and was abandoned in the following year.

Several projects were, however, started in this country for constructing tunnels under rivers by means of shields and by other methods, such as cofferdams and caissons. Acts of Parliament were

obtained in some cases, and in others refused; but nothing was actually accomplished until 1886, when the City and South London Railway tunnels were commenced. In one case, however, that of the North and South Woolwich subway, a contract was let in 1876, and a shield with air-locks, hydraulic segment-lifting apparatus, and other machinery, and a large quantity of the cast-iron segments, were actually constructed to the author's designs for driving through the sand and gravel forming the bed of the river Thames. The contractors, however, owing to difficulties elsewhere, abandoned their contract. The late Mr. T. A. Walker, who did not believe in the shield method, expressed his willingness to carry out the work in his own way, which was to drive the tunnel through the chalk underlying the gravel. In the absence of financial strength, Mr. Walker's offer was accepted by the directors, and he was allowed to proceed with the work; but, having sunk a shaft into the chalk he found it impossible to proceed far with the tunnel, even though compressed air, without a shield, was tried, and the undertaking was subsequently abandoned.

In constructing the City and South London Railway tunnel through loose water-bearing strata, compressed air was, in 1887, used in combination with shields.

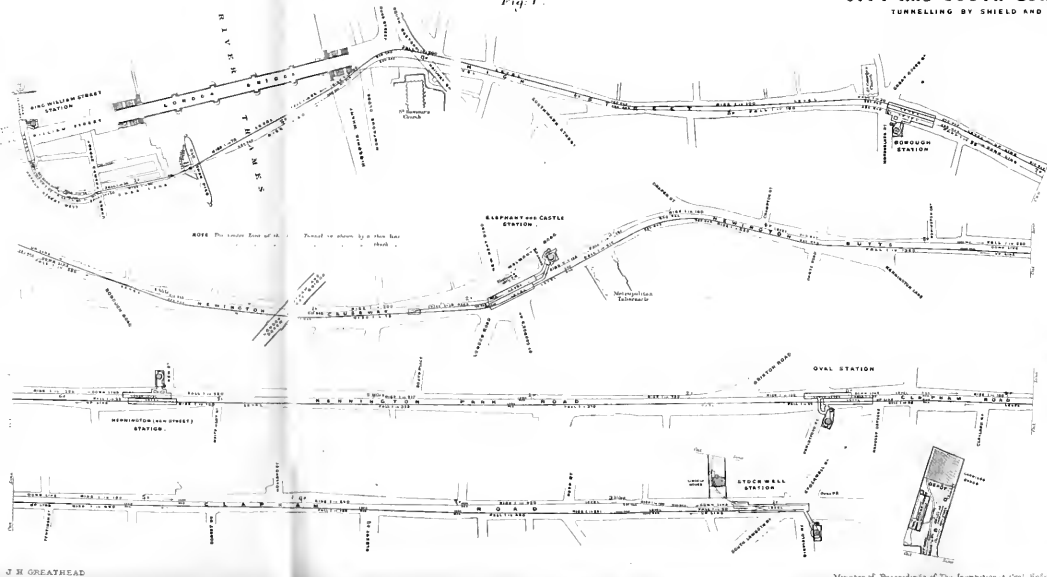
Lord Cochrane, in 1830, took out a patent for "apparatus for excavating, sinking and mining," being, to quote his specification, "an apparatus for compressing atmospheric air (into and retaining the air so compressed) within the interior capacity of subterraneous excavations....in order that the additional elasticity given to and maintained in the included air by aid of my apparatus....may counteract the tendency of superincumbent water to flow by gravitation into such excavations....and which apparatus, at the same time, is adapted to allow workmen to carry out their ordinary operations of excavating, sinking and mining....within the space which is filled with compressed air, and also allow workmen ready passage to and from the space into the open air...." In his specification Lord Cochrane describes his apparatus as being an air-lock or locks, a water-column shaft and chain-dredge for materials, to be applied for sinking shafts or driving tunnels. The patent was taken out at the time that the Thames tunnel was under construction, and the drawing shows a shaft and tunnel, the latter in clay, with air-locks in the tunnel, and an open end under the river. The patent has often been referred to as providing perfectly for the sinking of shafts through loose water-bearing strata, but it makes no provision for tunnelling through such materials beyond the air-lock; and, indeed, Lord Cochrane does not appear to have contemplated the use of compressed air in tunnels, except in materials impervious, or nearly impervious, to air and water, such as soft clay.

Compressed air was not used in the Thames tunnel, nor, so far as the author is aware, in any tunnel for many years. It was used without a shield in the first portion of the Hudson tunnel, commenced in 1879, where the work was in almost impervious and

CITY AND SOUTH LONDON RAILWAY

TUNNELLING BY SHIELD AND COMPRESSED AIR.

Fig: 1.



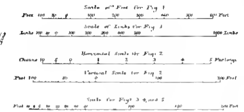


Fig. 2.

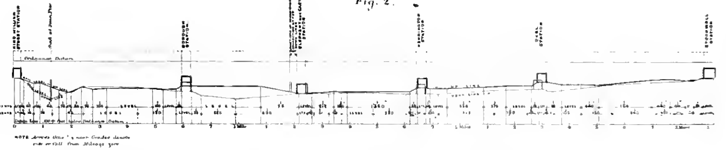


Fig. 3.

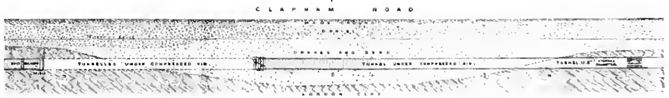


Fig. 4.

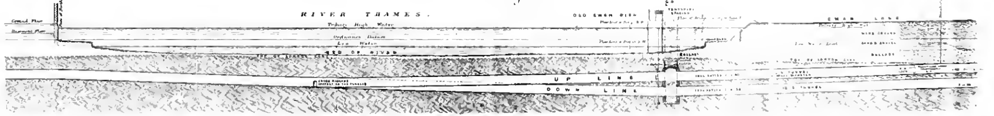
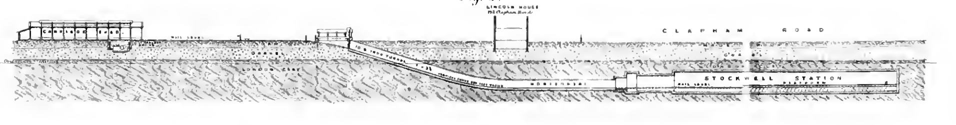


Fig. 5.



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obtained in some cases, and in others refused; but nothir
actually accomplished until 1886. when the City and South L

fairly solid material; and also in a four-foot ten-inch by three-foot ten-inch and almost rectangular tunnel composed of cast-iron plates at Antwerp in very fine silty sand in 1879. The Hudson tunnel was, in 1889, proceeded with under the advice of Sir John Fowler, Sir Benjamin Baker, and the author, with a shield in combination with compressed air and cast-iron lining.

The first shield of the eighteen used on the City and South London Railway was almost identical in its design and construction with that shown in Figs. 11, 12 and 13, Plate IV, which represents a shield for the ten-foot six-inch tunnels constructed between the "Elephant and Castle" and Stockwell. It consists of a cylinder five feet eleven inches long, of steel plates in two thicknesses of one-quarter inch each, riveted together to break joint with rivets countersunk on both sides. This cylinder was bolted to a strong ring of cast-iron at the front end, and to this ring were bolted the plates and channel-bars forming the face, and the adjustable steel cutters. The latter were so attached that they could be adjusted to cut out the excavation to the same diameter as, or wider than, the steel cylinder following them; the latter provision being necessary for passing round curves in any direction, either horizontal or vertical. In the face was provided a rectangular opening with iron doors upon rollers for sudden closing. It was, however, found in practice almost impossible to maintain these doors in working order, so they were subsequently removed and reliance was placed on timbers cut and kept ready for dropping into the channels placed for the purpose at the sides of the doorway. These were always used when work was suspended at a face, or when wet material was encountered pending the provision of appliances for dealing with such material. The inside of the cylinder in rear of the face was lined with massive cast-iron segments; and to these were bolted, as shown in Fig. 11, Plate IV, six hydraulic presses of six and one-half inches diameter. The presses were connected with two hand-pumps, for forcing the shield forward. The same pumps served also to run the rams back into the presses. To the projecting ends of the rams were attached long shoes for carrying the pressure on to the solid part of the cast-iron tunnel-lining without bringing any bending strains upon the rams, or undue pressure on the tunnel-flanges. The rear end of the shield, for a length of two feet eight inches, consisted only of the steel cylinder; and within this the cast-iron segments forming the tunnel-lining were put together.

The tunnels on the first or City section are ten feet two inches in diameter, and were composed of rings one foot seven inches long, each ring consisting of six segments and a key-piece, Fig. 14, Plate IV. Southwards of the "Elephant and Castle" they are ten feet six inches clear diameter, Fig. 15, Plate IV, in rings, one foot eight inches long. The flanges of the tunnel are three and one-half inches deep and one and three-sixteenths inch thick, and the plates are nearly one inch thick on the City section; on the Extension the flanges are three and five-eighths inches deep and plates seven-

eighths inch to fifteen-sixteenths inch thick. All holes were cast in the plates and flanges, and in no case was there any tooling of any kind upon the plates. They were cast from soft grey pig and dipped into a composition of pitch and tar while hot, which formed a good tenacious glazed coating upon them when cold.

The joints are shown in Fig. 16, Plate IV, and were found to be satisfactory. In the horizontal joints were placed, at the time of erection, soft pine packings one-quarter of an inch thick; and in the vertical joints a rope of tarred hemp between the bolts and the "chipping edge." Subsequently the whole of the joints were packed or pointed with Medina cement. Where, however, the tunnels were driven through water-bearing strata, iron cement was caulked into the joints in place of the Medina filling, and with excellent results, for the tunnels in these positions are absolutely watertight. These caulked joints were made before the compressed air was taken off.

The shields were at first not made to do any of the excavation beyond the shearing off by the adjustable cutters of a thin slice of material round the circumference; but subsequently in driving through clay, the author introduced a series of wedges or piles in front of the face. These were fixed in position against the front of the shield, and were made to enter the solid clay about two feet in advance of the cutting-edge by the hydraulic pressure driving the shield. The effect was to expedite the work and reduce its cost materially, the speed being practically doubled. The wedges were free to pass by the nodules of septaria, common in the London clay, without unduly straining the shield or presses. The timbers of the small heading, driven about six feet in advance of the shield, were, for a length corresponding to the advance of the shield, previously slackened to allow movement of the material inside the circle of wedges to take place towards the heading.

In the second half of 1888, two and one-fourth miles of the tunnels were driven, or an average of nearly 2,000 feet per month, or about eighty feet per day, at an average of six working faces. Frequently 100 feet per day were accomplished; and for long periods the tunnels in clay were carried forward thirteen feet six inches at each face per day of twenty-four hours, divided into two shifts. It is worthy of remark that the men, who were miners and laborers from railways, sewers and similar works, showed remarkable readiness in adapting themselves to work so different from any to which they had been accustomed. Starting with a conviction that the new system was inferior to that to which they had been accustomed, and not hesitating to express their opinions, they soon came to see that the innovation had merits of its own, and eventually that it was superior to the old method. Once satisfied on this score, they threw themselves into the work; and men whose lives had hitherto been spent in filling and running "muck," were to be found bending their energies to the working and guiding of the shields, erecting the iron, performing the grouting operations, and making the joints, with method and celerity. During the whole progress of the works

there was no fatal accident, speaking well for the forethought of the contractors and the carefulness of the men.

The shield should be very strong at its front end; and, unless in fluid or semi-fluid material, the tail end need not be very stiff. In all cases where the diaphragm forming the face has been placed well forward, and as near as possible to the cutting-edge, which has been made very stiff, no trouble has arisen. Any change of shape, however slight, at the cutting-edge must, as the shield progresses, tend to increase, and will inevitably lead to trouble. By increasing the strength at the front end, and reducing the shell or cylindrical plates of the tail-end to the minimum, consistent with safety, the annular space left by the advance of the shield round the outside of the tunnel-lining is reduced, and the quantity of grouting correspondingly diminished. This shell has been generally made in two or more thicknesses of steel plates, with rivets countersunk on both sides, thus giving a smooth surface both inside and out, without projecting cover-plates.

The doorway in the face of the shield should be placed as low as possible, in order that where the use of compressed air becomes necessary the portion of the face of the shield above the opening may form a safety-screen in the event of a sudden inflow of water, accompanied or not by material from the outside. The water could not, of course, rise above the lower edge of this screen so long as the pressure of the air is maintained. The advantage of a screen in this position is that it is always at the front. The joint between the shield and the tunnel is always good enough to prevent great escape of air, and can by proper grouting be kept almost air-tight, even while the shield is being moved.

SEGMENT-LIFTING.—The author designed, in 1873, for the Woolwich subway a hydraulic segment-lifting apparatus which was made, and on trial, found to work admirably. The segments of the South London tunnels, however, weigh only four and one-half hundredweight each; and it was found that six men could easily and quickly place the six segments in their respective positions, using for the upper two and for the key-piece a light temporary stage, necessary in any event for bolting together the rings and segments. Small pulley-blocks were found useful for slinging the lower side segments, but beyond these no other mechanical appliances were employed. The objections to the employment of any lifting appliance in a small tunnel are that it interferes with other operations, it does not save time, and is somewhat costly to make and maintain. In large tunnels, however, some such apparatus is essential, the segments being too heavy to handle and having to be lifted considerable heights.

HYDRAULIC PRESSES IN THE SHIELD.—The hydraulic presses in the shields used in the City and South London Railway were supplied with water from two cisterns placed inside the shield by hand-pumps one on each side of the platform in the shield, Fig. 11, Plate IV. These hand-pumps generally forced the

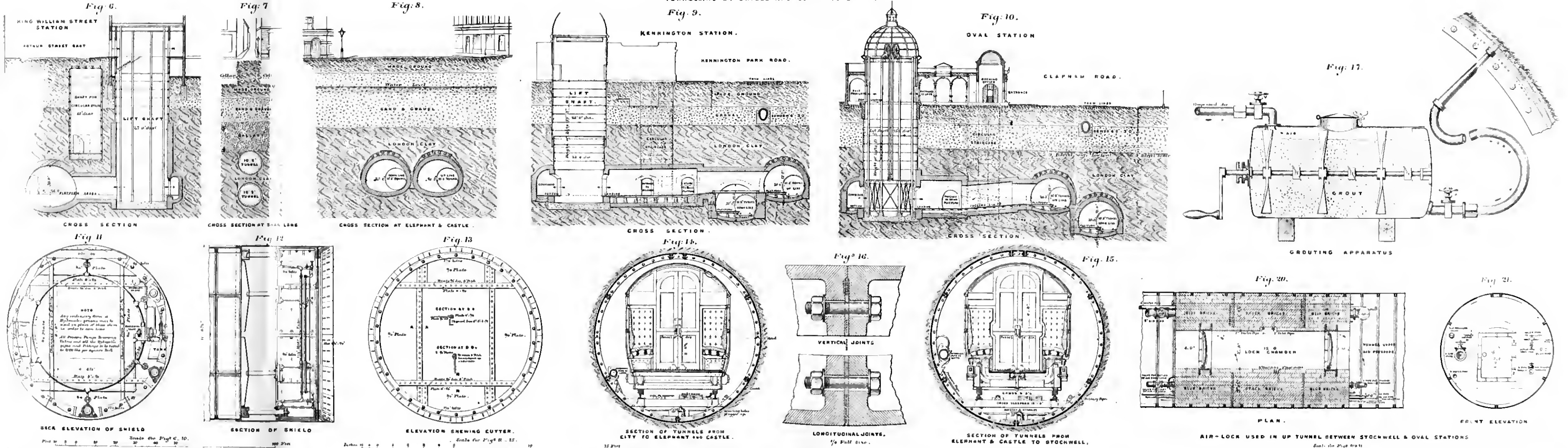
shield forward in about ten minutes, overcoming the skin friction and the resistance due to wedging and cutting the clay in the face. The pressure varied between 500 pounds and 1,800 pounds per square inch, depending upon the number of presses in use, the projection of the cutters, and whether the tunnel was being driven in a straight line or on a curve. A reversing valve enabled the rams to be driven back by the same pumps either singly, in groups, or all together.

In the case of large shields having a great number of presses, and requiring a considerable volume of high-pressure water, or where the pressure required to advance the shield is very great, it is expedient to set up a pumping-plant on the surface for the propulsion of the shield. This involves the fixing of high-pressure pipes between the surface and each shield with sliding or flexible connections at the shield. To avoid this, electric motors placed in the shield may be employed, especially when electric-lighting and haulage are used in the tunnel; or a small compressed-air engine may be used, deriving its supply of air from that used for grouting and ventilation. Where the work is proceeding under compressed air, the air-engine may simply have its exhaust carried back through the bulkhead; though, as a rule, the latter arrangement would require a large engine because of the comparatively low pressure, twenty pounds to thirty pounds per square inch, thus available for working it. In long tunnels up to sixteen feet or seventeen feet in diameter it would, however, be difficult to improve upon the simplicity, handiness and small cost of the hand-pumps in the shield. Very little time would be gained by the use of mechanical power, though the men would be saved some fatigue.

GROUTING BY COMPRESSED AIR.—In the construction of the Tower Subway, grouting was employed to fill the cavity left by the advance of the shield. This was accomplished by a hand syringe, the lime being mixed with water in a tub. The result was not satisfactory because the grout had to be sufficiently fluid to flow into the syringe, and was too fluid for good work, and the pressure that could be applied by the syringe was not sufficient to force it properly home into the spaces to be filled; moreover, this method of working could only be employed upon a very small scale. The author, some years later, devised the grouting apparatus first used in the City and South London tunnels, Fig. 17, Plate IV. A cylindrical vessel, capable of withstanding a pressure of seventy pounds or eighty pounds per square inch, has through its axis a shaft or spindle working in a stuffing-box at each end of the vessel, and provided at one or each end with a handle outside, and carrying, inside the vessel a number of paddles. The lime and water are introduced through an opening at the top, having a lid capable of being closed air-tight; and the mixture is discharged by compressed air through a length of flexible hose-pipe ending in a branch and nozzle, the nozzle being inserted in holes in the tunnel lining provided for the purpose. The smaller grouting pans are usually

CITY AND SOUTH LONDON RAILWAY

TUNNELLING BY SHIELD AND COMPRESSED AIR.



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worked by two men; one continually keeps the paddles revolving and opens and closes the air-and discharge-valves, while the other has charge of the branch at the end of the hose. As the space is gradually filled, the holes through which the grouting is discharged are successively closed. Beginning at the lowest hole, grout is forced in until it reaches the hole above it; the lower hole is then plugged and the nozzle applied to the higher, and so on until finally the highest hole, in the key-piece, is reached, and the full pressure is brought upon the grout.

After experiments with Portland and Medina cements and blue lias lime, the author came to the conclusion that the last was in some respects preferable; and, as it was much cheaper than the cements, he adopted it for the City and South London Railway tunnels. Portland cement has, however, been used in some cases, and for special purposes Medina has been found to work well. The blue lias lime may be mixed with or without sand, and does not set hard suddenly like cement. It can be mixed with only so much water as it will retain in setting, it adheres to the surface of the iron firmly, and when fresh and used hot it expands in setting. No reliance being placed on the surrounding shell for strength, there is no object in having a shell harder than solid London clay. An admixture of sand has not been generally used with the lime, the extra trouble of mixing and handling the two materials is hardly repaid by the small saving in cost over pure lime. It is very important that there should not be an excess of water with the lime or cement, because shrinkage will follow the throwing off of the excess in setting, which will be greatly retarded and be very uncertain. Medina cement for grouting purposes appears also to be better than Portland cement, but it has not the quality of cheapness as compared with blue lias lime. At the stations of the railway about 2,000 feet in length of the smaller iron-lined tunnels gave place to the larger brick-lined station tunnels, affording an excellent opportunity of observing the condition of the grouting. It was satisfactory to find that the work was in every way perfect. The tunnels were everywhere encased and every cavity had been filled. In some cases where nodules of septaria had been broken and moved by the cutting-edge of the shield, the lime had penetrated through cracks in the stone and had filled the cavities behind the stone, the lime filling the cracks themselves, being sometimes not thicker than a sheet of thick paper.

The compressed-air grouting was found to be a very important factor in the work—not only for preventing movements overhead and deformation of the tunnels, but also for several other purposes. Its uses in connection with tunnelling under compressed air to prevent the escape of the air and for making air-tight locks, and in connection with the sinking of iron-lined shafts, I referred to under those heads. It was also found to be most useful in cases where valuable property, such as wine vaults, had been disturbed by the construction of the brick-lined tunnels. All that was necessary to

make the walls quite solid was to point the cracks with cement; and when the pointing had set to inject the grouting so as to completely fill the cracks, vents being provided for the escape of the air and for observation. In a similar manner a railway bridge, elsewhere, cracked by movements caused by the tipping for an embankment, has been restored and rendered secure at a trifling expense.

The supply of compressed air used for grouting also afforded the means for ventilating the long tunnels during construction. It was found that by allowing the compressed air from time to time to escape when it was not required for grouting operations, by a slight opening of the controlling-valve, not only was good air secured at the face, but the temperature was reduced by the expansion of the air, and the usual large pipes and blowers were rendered unnecessary.

HAULING UNDERGROUND.—In the earlier parts of the work a timber flooring was laid upon long temporary sleepers, resting at their ends upon the iron lining; and the excavated material was run out, and the iron, etc., brought in, by manual labor. Subsequently the flooring was abandoned, the invert was filled with clay, and the work was accomplished by ponies upon a very unsatisfactory road. Electricity will probably be found to be the best and cheapest means. It has been introduced in the Waterloo and City Railway tunnels, where two small electric locomotives, built by Messrs. Siemens Brothers & Co., do all the traction work.

TUNNELLING IN LOOSE WATER-BEARING STRATA. —At several points on the two sections of the railway compressed air was employed in passing through water-bearing strata. The most notable case was near the south end of the railway at Stockwell, where for a length of about 200 yards the two tunnels were carried through coarse gravel and sand under a head of about thirty-five feet of water. The longitudinal section of this length is shown enlarged in Fig. 3, Plate III. For the purpose of this work compressors were erected, and the air was carried a distance of about 300 yards through a six-inch pipe from them. The tunnels were driven under the normal air-pressure to a point where the cover of clay was reduced to about five feet; whence, the air-locks, having been erected previously, they were continued under compressed air. It was generally found that the ballast immediately overlying the clay was more open, that is, contained less sand, and that of a coarser character, than in other positions; it was in passing through this very open material that the work was most difficult. The driving of a tunnel is wholly different from the sinking of a vertical shaft under compressed air. In the latter case a uniform pressure of compressed air balances an equal uniform pressure of water; while in the former a practically uniform air pressure is employed to keep in check a varying pressure of water, the extent of the variation depending upon the height of the face operated upon. For instance, in the Stockwell case, the water pressure at the top of the tunnel would be that due to a head of about 25 feet;

while at the bottom the pressure would be that due to a head of $36\frac{1}{2}$ feet. If the material be close, such as silt or fine sand, there is not much difficulty, provided there be a sufficient cover of material, because the porosity is not so great as to allow of the escape of a large volume of air, while maintaining a pressure sufficient to keep the bottom sufficiently dry. In very coarse sand, or, still more, in ballast having but little sand in its composition, it would be impossible to maintain a pressure much higher than that due to the head of water over the top of the tunnel without special appliances and precautions. The difficulty consists in having to work upon, so as to remove, the material from the front of the shield for the whole height of the face, and at the same time to prevent the inflow of a large volume of water, or the escape of an inordinate volume of air. The inflow might involve nothing more than danger to surrounding structures, where such existed, or it might mean absolute impracticability. In other cases, such as coarse gravel or fissured or very porous rock, it might involve prohibitive expense in pumping. The outflow of air on the other hand, might, in certain cases, be such as to render tunneling impracticable, on account of the first cost of plant and the expense of working it. In porous material, therefore, where a large volume of water is to be expected, and the conditions are such as to render pumping impracticable, compressed air is only to be considered if means can be found for preventing its too rapid escape.

The author many years ago devised means for tunneling through such water-bearing strata, by working under compressed air with a shield having a face so arranged as to prevent the escape of any large volume of air, Fig. 119. The shield was constructed for use

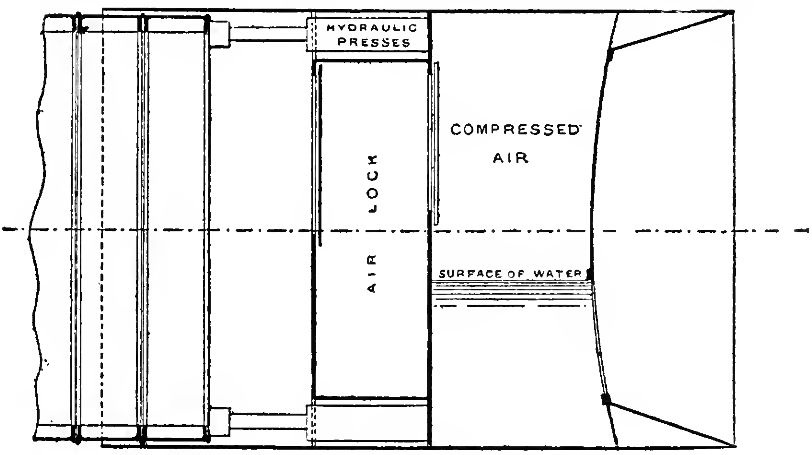
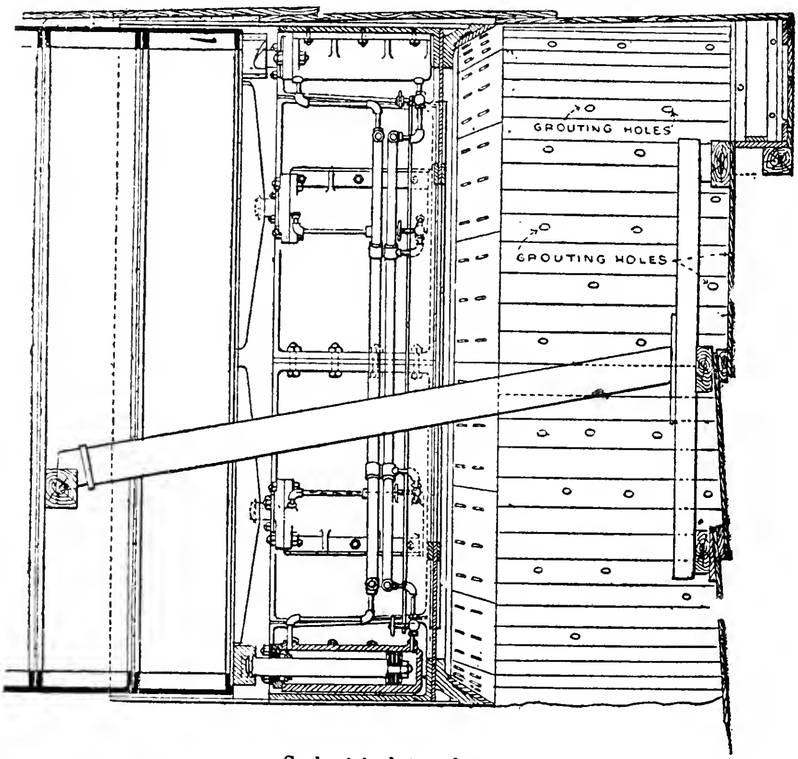


FIG. 119.

in the North Woolwich Subway already referred to. It is also practicable, as the author has proved by experiments upon a small scale, to remove the material from the path of the shield in certain materials by mechanical means, or by a current of water, or by the two combined. In such cases the men might work under a reduced, or even under the normal air pressure, at depths below that at which

they can work at all under pressure. A machine for removing the sand and gravel at Stockwell by mechanical power was constructed and held in readiness for use; but the method first tried was found to work well and was employed throughout.

The shield having been brought to the water-bearing strata, a small heading was driven at the top in advance of the shield, stout poling-boards being used to support the top, resting at one end upon the forward end of the shield; the heading was then widened out and the polings continued until about three-fourths of the circumference and the whole of the face had been poled, Fig. 120.



Scale, ¼ inch to 1 foot.

FIG. 120.

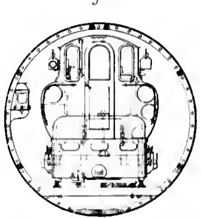
In an ordinary way the polings would not sufficiently prevent the outflow of air, but by frequent injections of lime grout under compressed air, through holes in the polings, as well as through the holes in the iron lining, the escape of air was so reduced that the compressors were not overtaxed. The action of the grout in preventing the escape of air was immediate.

The two tunnels were driven in this manner, side by side, under the large mains of the Lambeth and Southwark and Vauxhall Water Companies, supplying a large area of South London, and under sewers and tramways without the slightest disturbance; and this system has since been followed in driving several tunnels under the Clyde and elsewhere in Glasgow through sand, silt, etc. The speed attained under compressed air in the gravel on the City and

CITY AND SOUTH LONDON RAILWAY

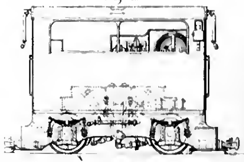
TUNNELLING BY SHIELD AND COMPRESSED AIR

Fig 22



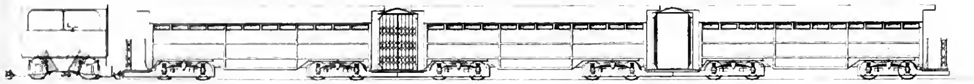
CROSS SECTION OF 10' 6" TUNNEL

Fig 23



ELECTRIC LOCOMOTIVE (MESSRS SIEMENS)

Fig 26



ELEVATION OF TRAIN

Fig 24

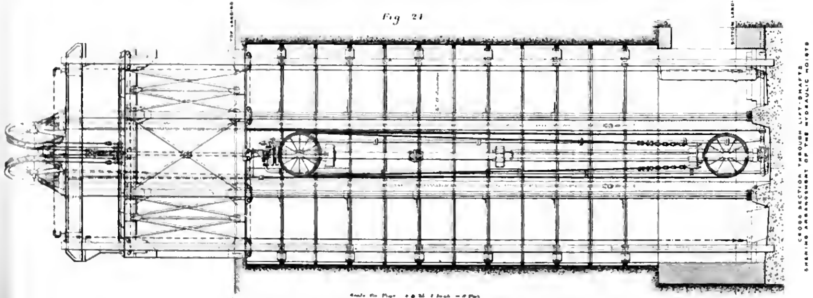


Fig 25

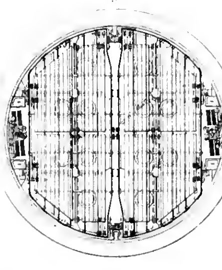
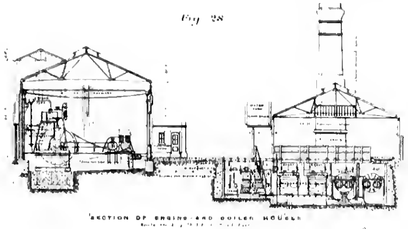
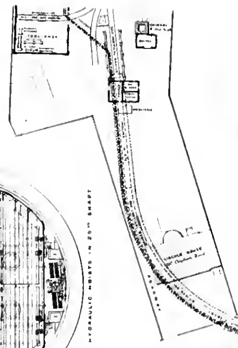


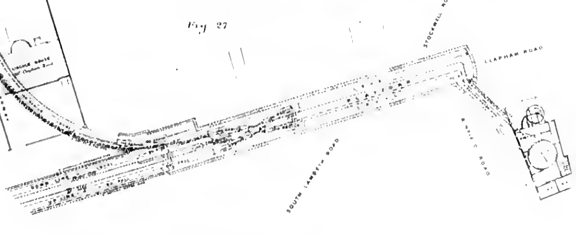
Fig 28



SECTION OF ENGINE AND BOILER HOUSES

Fig 27





PLAN SHEWING ARRANGEMENT OF STOCKWELL STATION

J. H. GREATHEAD

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South London Railway was at each face between 4 feet 6 inches and 5 feet per day of two shifts. The men were found to bear the compressed air without ill effect. They were the same men as had worked through the ordinary tunneling, but the pressure was not more than about 15 pounds per square inch above the normal.

It is sometimes advisable, and even necessary, to work with an air pressure below that due to the maximum head of water in the material at the face. For instance, in working in fine sand, by allowing a small inflow of water to take place much below that necessary to carry the sand with it, the pressure of air may be reduced very considerably. This reduced pressure is sometimes of great advantage. The workmen are benefited, and in some cases the work may be more safely carried out, as where there is a comparatively small cover of loose material under a river. In this latter case, a pressure in the tunnel corresponding to that of the head of water at the lowest point of the face, being in excess of that due to the head of water at the highest point of the face, by an amount depending upon the height of the tunnel, or of the portion of the face operated upon, would, in some cases, when the combined pressure of the covering material and the water is less than that of the air in the tunnel, be sufficient to lift or blow up the cover at the face, resulting, probably, in an inrush of water attended with risk to life and other serious consequences; unless other precautions, such as adding weight above or below the material, be taken. It may, also, in more open material, such as coarse gravel, be more economical to pump even the considerable volume of water which would enter with a maximum head equal to the height of the face operated upon, rather than pump the volume of air which would escape through the opening. The average head would be half the height of the opening, and would be independent of the total head of water over the tunnel, the latter being balanced by the air pressure in the tunnel.

AIR-LOCKS.—The first air-lock used was of iron fixed in a bulkhead of brickwork. This was, however, found to be small and inconvenient, and the later air-locks were formed by reducing the size of the iron tunnel by a thick lining of brickwork and concrete, into which two cast-iron door-frames were built, Figs. 20 and 21, Plate IV, leaving a space 12 feet long, 3 feet 9 inches high and 3 feet 9 inches wide for the passage of men and materials. To render this combined bulkhead and lock air-tight, a vertical space of about 3 inches was left in the brickwork at each door-frame, and subsequently filled with Medina cement forced in by the grouting apparatus under a pressure of about 40 pounds per square inch. This was found to make an absolutely air-tight barrier. In addition to the main chamber, pipes were built in and through the brick work of size and length sufficient for passing the temporary rails, pipes, etc., through.

These easily constructed brick air-locks possess the advantage over the iron air-locks first used of mitigating the chilling effect, due

to the reduction of pressure, upon the men, hot from their exertions in the warm compressed air, in their egress. The brickwork, absorbing heat when the lock is open to the compressed air, and parting with some of it during the reduction of the pressure when closed against the compressed air, is found to preserve a more equable temperature than the thin plates forming the walls of the iron locks.

When the compressed air is carried a considerable distance through pipes to the bulkhead its temperature may be sufficiently reduced; otherwise measures should be taken to keep down the temperature of the air in which the men work. A spray of water on the outside of the pipes and receiver has been found to answer well.

The workmen employed in the compressed air on the City and South London Railway did not suffer from partial paralysis or "bends." It is true the pressure was not high—about 15 pounds per square inch—but from observations on this and other works the author considers that purity or impurity of air has perhaps more effect than pressure upon the health of the men engaged, provided due precautions are taken as to entrance and exit, and the avoidance of chills. It is noticeable that when tunnels have been driven through almost impervious material, as under the Hudson and St. Clair Rivers, and where consequently the quantity of air pumped has been comparatively small, the cases of "bends" were numerous; while in the gravel in London, both at the City and South London Railway and more recently at the Blackwall Tunnel, with a higher pressure, there were in the one no cases at all, and in the other no fatal cases of "bends." Where tunneling is proceeding in fine sand or in silt, which are almost air-tight, the delivery pipes from the compressors should be extended to the face as the work progresses, in order that the air used in locking may assist the ventilation in the whole tunnel; and provision should be made for a copious supply of air to be delivered at the face. The more highly compressed air employed for grouting is useful for this purpose and for cooling the air, by expansion through a throttled passage, at the same time. In one instance, at least, this supply has on a serious emergency proved invaluable. In carrying the tunnels of the Glasgow Subway under the Clyde at St. Enoch's a fire occurred, filling the tunnel with suffocating gases and cutting off the men from the air-lock; and but for the air from the hose of the grouting apparatus the whole gang would have perished. By lying down and receiving the air in their faces the men were able to live during the several hours that it took to reach them by breaking through from the second tunnel.

IRON TUNNELS.

SHAPE OF TUNNELS.—The circular section will be found to be generally the most suitable for iron-lined tunnels. In a perfect fluid, with the weight of the lining equal to that of the fluid dis-

placed by the tunnel, a circular section, being free from any bending moments, would be theoretically as well as practically the best. In material not fluid enough to flow round the tunnel lining, the circular section is again the best, because the material surrounding the tunnel affords abutments solid enough to prevent change of shape, insuring here also absence of bending strains; this applies to all clays as solid as the London clay, and to all gravels and clean sands. For such materials as silt and very soft clays, the circular section would involve bending strains on the lining; but the more nearly fluid the material, the less severe would be the bending strains.

It is convenient to have all the segments of a ring as far as possible alike and interchangeable; and for this reason alone, it is hardly worth while to depart from the circular section for the saving of a comparatively small quantity of excavation. But in soft material a departure to any considerable extent from the circular section, as for instance, the introduction of a flat invert with sharp junction curves between the invert and sides, would generally involve a considerable addition to the weight of the lining to enable it to withstand the unequal pressure.

Cast-iron tunnels possess several advantages over brickwork or masonry tunnels, even where the latter are practicable. They can be made perfectly watertight whatever the pressure of the water surrounding them may be. They can be made stronger than any brick-lined tunnel because, unlike the latter, high pressures do not involve any appreciable enlargement of the outside dimensions of the tunnel; while in the case of a brick lining, after a certain thickness is reached any addition to the section adds but slightly to the strength. Where excavation is expensive or difficult, the area required for an iron tunnel, being materially less than that required for brickwork or masonry, iron tunnels may be constructed in some cases more cheaply, and in all cases with greater safety. As soon as the iron lining is erected the tunnel is practically complete. Iron tunnels are better adapted for construction by shield, and their construction may proceed with much greater rapidity; and thus in large cities there is less interference with traffic by reason of the entire absence or the reduced number of temporary shafts in the streets.

The following table gives the ratio of the area of excavation to the internal clear area of tunnel in several cases of brick and iron lined tunnels—the clear area being taken as 1:

	Ratio of area of excavation to internal area of tunnel.
Brick—	
Railway tunnel in clay, 25 feet wide, double line	1.60
Railway tunnel in clay, 15 feet wide, single line	1.60
Thames tunnel, two openings, each 14 feet wide	2.22

Iron—	
City and South London Railway, 10 feet 6 inches internal diameter	1.17
Waterloo and City Railway, 12 feet 9 inches internal diameter.	1.17
Glasgow Harbor, 16 feet internal diameter	1.16
St. Clair, 19 feet 10 inches internal diameter	1.17
Hudson (cast-iron), 18 feet internal diameter	1.22
Blackwall, 25 feet inside iron	1.22
Blackwall, 24 feet 3 inches inside glazed face	1.30

COMBINED IRON AND MASONRY LINING.—Iron alone can be made of the requisite strength and stiffness for the lining of a tunnel of any size. Brickwork or concrete inside the cast-iron should not be relied upon for strength, the two materials being so different in character that they could not be assumed each to take a definite portion of the pressures; and to add internal brickwork for the sake of stiffness is to unnecessarily increase the area of excavation. Any such increase, especially in the case of large subaqueous tunnels, is to be avoided as adding to the difficulty and cost of the work. It is generally desirable, however, to introduce a lining of concrete between the internal flanges of the iron, and perhaps a little beyond to give a smooth internal face, the whole of the iron being thus embedded in lime or cement inside and out. The smooth internal face is also desirable in the smaller railway tunnels as being less noisy and offering less resistance to the flow of air than the unlined iron with projecting flanges.

Since the tunnels of the City and South London Railway were constructed, a number of other cylindrical iron-lined tunnels have been similarly executed of greater and smaller diameters, for various purposes, in England and abroad.

WATER SUPPLY FOR GOLD MINING

AT DAHLONEGA, GA.

BY H. B. C. NITZE AND H. A. J. WILKENS, BALTIMORE, MD.

(*Trans. of the American Inst. of Mining Engineers, Vol. XXV.*)

The system of reservoirs, ditches, etc., in this district is by far the most extensive and best equipped in the Southern gold-belt. The principal water-line is known as the Hand and Barlow ditch, having a total length of thirty-four miles, the main canal being twenty miles long, six feet wide and three feet deep, and furnishing 800 miner's inches. The grade averages five feet to the mile, being four and one-half feet on straight lengths, with slightly steeper grades on bends. The cost of digging this canal was about $1 per rod; the total cost, including trestling, etc. (excluding siphon-line), was $1,000 per mile. The canal crosses the Yahoolah valley about one mile northeast of Dahlonega, in a wrought iron siphon pipe 2,000 feet in length. The difference in level of the two ends

is about six feet. The inside diameter is three feet, the thickness of the pipe being 3-16ths of an inch in the upper and 3-8ths of an inch in the lower part. It was built in 1869.

Four miles from Dahlonega the water is carried across a similar depression in a wooden tube which is 7-8ths of a mile in length and three feet in outside diameter. It is made of 3x5-inch staves, trimmed so as to make a tight fit. These staves are laid in wrought iron hoops, forming alternate joints; the last stave is driven in with a maul. This tube was built in 1868, and is still in good condition.

Auxiliary ditches run off from the main canal to the various mines. A portion of this water was formerly leased out at the rate of 12 cents per miner's inch for twenty-four hours. The present owners, The Hand & Barlow United Gold Mines and Hydraulic Works of Georgia, are, however, at present using the whole amount in working their own mines. Besides this system there are several smaller ones, bringing the total length of ditch-lines up to about eighty miles.

A unique feature of the water supply at the Findley mine is the elevation of the water from the ditch-line to a reservoir situated 152 feet above it, by means of a hydraulic pumping engine made by a Filer & Stowell Company, of Milwaukee, Wis. This pump is situated near the stamp-mill, 285 feet below the ditch-line. The water is led to it from the above ditch in a sixteen-inch straight-riveted feed-pipe 456 feet in length, and is discharged by it into a reservoir of 88,000 cubic feet capacity, a total vertical height of 437 feet, through a twelve-inch steel pipe 1,141 feet in length. The principle involved is that of the hydraulic ram, inasmuch as a large quantity of water under a lower head raises a certain portion of itself to a higher head, the remainder being waste. The machine, however, is of entirely different and, so far as known, novel construction. It is of the duplex pattern, the two engines being connected by gearing and with an eight-foot fly-wheel. Each engine has three cylinders in tandem, to which the water under the feed-head (123 pounds) is admitted and discharged by valves of the Riedler type. In one of these cylinders the water is raised to the greater head (190 pounds) at the expense of the feed-water, under head, going to waste in the other two. A shifting-valve is attached to the latter to give relief to the valves. The stroke is eighteen inches, and at a high piston-speed of 250 feet per minute the pump works very smoothly. Tests had not been made, and no figures of efficiency could be obtained at the time of our visit. Such figures, as well as a more detailed description than could be made after a hasty examination, would be of great interest. The present working capacity of the pump is 600 gallons per minute.

NOTES ON THE UNDERGROUND SUPPLIES OF POTABLE WATERS IN THE SOUTH ATLANTIC PIEDMONT PLATEAU.

By J. A. Holmes, State Geologist, Chapel Hill, N. C.

Trans. of the American Inst. of Mining Engineers, Vol. XXV.

It is a fact that is coming to be more widely recognized by the general public, as well as by members of the medical fraternity, that the health of persons living in our hill-country depends in no small degree upon the drinking water obtained, just as it has been found that the use of pure water in the low-lands and swamp-areas of the Southern States results in practical immunity from malarial diseases. Hence the problem, how to obtain supplies of wholesome water for the towns and manufacturing establishments in the hill-country or Piedmont plateau-region of the Southeastern States, becomes one of considerable interest, the importance of which will continue to increase, as the favorable conditions for manufactures and agriculture in this region will make it, in the near future, the most thickly populated portion of the South Atlantic States.

Water supplies from surface streams are unquestionably of the first importance; and in the mountain counties, where the region is still largely forest-covered and the streams are swift and continually aerated by rapids and cascades, the water is of superior purity and clearness. This statement is also applicable to the more elevated and sparsely settled portions of the Piedmont plateau; but in the less hilly and more thickly settled portions of this region the streams are more sluggish, and the waters more muddy and less pure, owing to the fact that a much larger proportion of the surface is under cultivation. Furthermore, many of the towns and manufacturing establishments are located at distances from the large rivers and creeks too great to permit of the water being lifted and transported to them by pipe-lines at any reasonable cost.

Rain water, caught from the roofs of houses under favorable conditions, and kept in properly constructed cisterns, is probably the safest for drinking purposes; but under unfavorable conditions, and when not properly attended to, cistern water must be considered as not altogether safe; and, in any case, the supply is inadequate for large establishments.

Such being the case with regard to surface supplies of water, it will be seen that, in a number of cases, we must depend for potable waters upon the underground supplies. These may be obtained either from springs or wells. Of the latter, we may consider three varieties: The ordinary open well, such as is often seen about private residences; deep bored wells which penetrate the crystalline rocks in the endeavor to obtain artesian supplies of water; and the shallow bored wells which are put down through the soil to the surface of these crystalline rocks in the hope of striking under-

ground currents along the lines of contact between the lower portion of the soil and the upper portion of the undecomposed rock. In this latter case, generally, several such wells are bored within a short distance of each other, and these are connected by iron pipes, and water is pumped from the various pipes through a common pipe to a common reservoir or tank. This is what is generally known as the tube-well system.

The open springs furnish an excellent but limited supply of water for family use; a supply, however, which, though sufficient for the needs of isolated residences, is generally inadequate to meet the demand about towns and manufacturing centers. Furthermore, in such latter cases, and frequently even near isolated country residences, the surface in the neighborhood of the spring becomes so contaminated with decaying organic matter that the water becomes unfit for drinking purposes. The same general statement may be made concerning ordinary open or driven wells, which, for the sake of convenience, must be located near residences where the surface-soil becomes more liable to contamination as the region becomes more thickly settled. Examples of this are not infrequently seen where the water from wells and springs in newly settled communities is found to be healthful, but a few years later has become so contaminated with organic matter, which has permeated the soil from above, that sickness follows its use, and it must be finally abandoned. It is difficult, however, to get the average citizen to understand that the organic matter of the water in his well or spring may come from the soil immediately about his premises, as the prevailing notion concerning these supplies of water is that they come, not from the immediate vicinity, but from some distant region. Consequently, in many of our towns and even about the isolated country residences, the barn-yards and the privies and the hog-pens seem to be built upon the principle of convenience alone, which frequently places them in close proximity to the well or spring from which the family supplies of drinking-water are obtained.

But, outside of this question as to the purity of the water, the supply of water from isolated springs and open wells is generally quite inadequate for towns or manufacturing establishments of any considerable size, unless the number of these wells is greatly multiplied; and their multiplication means their wider distribution through the settlement or community, and thus a multiplication of the possible sources of disease from the drinking of contaminated waters. Nevertheless, the fact remains that many of the towns on this region, with a population of from a few hundred to several thousand, are still without any general supply of water other than that from independent shallow wells. And while the amount of disease in such cases generally increases with the age of the town, and the physicians, at least, recognize the increasing contamination of the water as the source of this increase in sickness, yet, for the lack of a better system, this one continues in existence.

Deep artesian well supplies are not to be depended upon, for the

reason that the geologic conditions in the Piedmont plateau region are not favorable. The rocks of this region are crystalline schists, gneiss and granites, with the dips (schistosity) generally steep and varying on both sides of the vertical. A considerable number of borings, varying from 100 to 1,000 feet in depth, have been made into these crystalline rocks in the Piedmont region of the two Carolinas and Georgia during the past few years, with the expectation of securing either an "artesian" (over-flow) supply, or a supply that would come near enough to the surface to be reached by the pumps. But the results have been generally unsatisfactory; the holes being "dry," or the supply of water being inadequate. A somewhat exceptionally favorable result was experienced in Atlanta. Some years ago (1881-82) a well was bored into the gneiss-rock in the heart of Atlanta to a depth of about 2,200 feet, at a cost of about $20,000. At 1,100 feet a large supply of water was tapped, which rose to within about seventeen feet of the surface. For several years this well constituted the water supply for a considerable part of the city; but the water was pronounced unsafe by the medical authorities, and the well has been abandoned in favor of a water supply from the Chattahoochee river. In a few other cases exceptionally large supplies of water have been reached; but, as a rule, the boring of these wells has failed of satisfactory results.

Some professional well-borers, like some professional miners, with a laudable desire to be kept busy, urge that the deeper the hole the better the chances of success, an opinion that has frequently but slight foundation in the case of the mines, and is, in the case of well-boring in this region of crystalline rocks, contrary to both theory and experience. The possibility of exceptions no one will deny, as we see that, in a few of the deeper mines of this region considerable streams of water are tapped; and in some cases there is a bare possibility that the hole to be drilled for a water supply may tap such an underground stream of water, as was the case in Atlanta; but the chances are more than ten to one against such "luck." As a rule, these crystalline rocks become harder and more solid as we descend, and the chances of securing a reasonable supply of water, which are never good after the hole enters the real mass of rock, may be said to decrease as the hole descends. There is, however, one certainty about this operation, namely, other things being equal, the deeper the hole the more rapidly the cost increases.

During the past few years the tube-well system mentioned above has been introduced in a number of communities in the Piedmont region with decided success in furnishing a good supply of drinking water to the smaller towns and manufacturing establishments. This system is based upon the existence of fairly well-defined underground "currents" of water, in regions where the topography is favorable, where the rocks have decayed to a considerable depth, and where, near the lower limit of this decay, there is more or less porous material, through which water may readily percolate. Of

course, it has been well-known in the past that more or less well-defined underground movements of water existed, that at favorable locations the small currents come to the surface as springs, and that frequently, both on elevated regions and about low-lands, when wells are sunk sufficiently deep into the soil,—usually near the surface of the hard rocks,—a sufficient amount of water is found either to empty into the well as a small stream or to ooze into it from the surrounding soil, and thus furnish a limited supply. But it is only recently that the location and extent of these underground sources of water have been investigated, in some regions with considerable care, and they have been found capable of yielding under proper treatment much larger quantities of water than have been reckoned upon in the past. This investigation has been prosecuted in this region mainly by Mr. Henry E. Knox, Jr., a hydraulic engineer of Charlotte, N. C., who has in this way located considerable supplies of underground water in regions where they were sorely needed.

I give below, in tabulated form, Table XXXIX, the results obtained by Mr. Knox in the Piedmont region of North and South Carolina. His method of investigation is to examine carefully the topography and geology of the region where the water-supply is needed. The topographic conditions favorable to success are, as might be expected, where there is more or less of a basin, shallow ravine or valley, so that the water which falls upon the surface, instead of running off in opposite directions, naturally percolates downward if the soil is sufficiently porous, and tends to concentrate along the lower portion of such basin or valley, where it may meet with least resistance in the more porous materials.

By way of exploring such a region, a number of holes are bored in line across the basin or valley, so as to determine the existence and location of such an underground "current" of water. In this way, its position at intervals is determined, and the intervening course is traced by additional borings. If the water supply is tapped by these borings it sometimes overflows; the quantity thus overflowing is measured, and pumps are then applied so that the possible yield of water can be estimated. In these underground "streams" the water usually follows the topographic conditions, as might be expected; but in some cases it moves more or less obliquely across the ravines, showing that the overlying soil has not the same thickness everywhere, i. e., that the topography of the soil-surface is not the same as the topography of the under-lying rock surface; and that the water current moves along down the incline of least resistance of the rock-surface, independently, in a measure, of the topography of the soil-surface.

The fact that the water percolates through this more or less porous material at considerable depths below the surface of course suggests that the movement must be sluggish; but that there is a definite movement is shown by the fact that where there are a number of holes bored at intervals along the line of the "stream," and

coloring-matter is introduced into one of them, the color appears in a short time in the water coming from the neighboring holes in one direction, but not in the water from the holes situated in the opposite direction. The average rate of movement, however, has not been determined with a sufficient degree of accuracy to admit of its being stated. These currents are quite limited in their width, ranging in the cases tested from a few feet to (in rare cases) more than 100 yards. And, as might be expected, the width is not at all constant; but while it gradually increases further down the "stream," as the supply of water becomes greater, yet this increase of width is by no means constant. The depth at which these underground water-currents have been found varies from about twenty to nearly 100 feet, and has been generally less than fifty feet below the surface.

The fact that, in the case of some of these wells, the water overflows at the surface is due to topographic rather than geologic influences. In some cases, especially at Charlotte, N. C., as mentioned in the table below, the flow from a single well amounts to as much as ten gallons per minute. Here, as in other places where the overflow is slight—even less than one gallon per minute—the amount of water which can be pumped from such a well is considerably larger. Thus, in the case mentioned at Charlotte (Latta Park), there are several over-flowing wells, with an average depth of forty-two feet. The maximum natural flow from one of these wells is ten gallons per minute, but with the application of a pump the eight wells yield readily 280,000 gallons per day. Again, at Chester, S. C., one well, the natural overflow of which is six gallons per minute, yields, with the aid of a pump, nearly sixty-two gallons per minute, or 89,280 gallons per day. In another case the maximum natural overflow of any one of the eight wells, bored at the Western Hospital at Morganton, N. C., is only four gallons per minute, while the eight wells, with an average depth of about thirty-nine feet, yield, upon the application of a pump, 165 gallons per minute, or 237,600 gallons per day.

The quality of the water obtained from these wells has been pronounced satisfactory in every case by the health officials. Of course, the continuation of this quality will depend largely upon the continued freedom from contaminating influences of these water-basins; and one advantage of this system of water supply is that the basins, being generally limited in area, may be generally controlled by one or more individuals, or by a corporation, and may thus be kept free from sources of contamination.

As might be expected, the search for underground supplies of water has not by any means been successful in every case; but the limited experience thus far gained leads to the belief that they may be found in a majority of communities, where search is extended over a sufficiently large area, and is made with sufficient care. It would at present, however, be too much to claim that these under-

ground supplies of drinking water can be found sufficient to meet all the demands of larger towns and cities, though they would prove of material service in this connection. But I anticipate that they will prove of greatest importance in connection with the water supplies of smaller towns and of more or less isolated manufacturing establishments, where there are usually several hundred or several thousand operatives.

The appended table contains a list of the more important places where these underground water currents have been found, and where the "gang-well" or tube-well system has been introduced; the name of the special establishments for which the wells were bored; the number of wells at each place; the average depth of the wells; the natural overflow per minute from that one of the series of wells from which the overflow is largest; and the aggregate yield of water is twenty-four hours from the wells at each place, when the steam pump is applied. The data for this tabular statement have been supplied by Mr. Henry E. Knox, Jr., who bored all of these wells, and who states that out of twenty-three surveys made by him only three were unsuccessful in locating the desired quantity and quality of water.

TABLE XXXIX.

List of Flowing Wells in the Piedmont Plateau Region of North and South Carolina.

PLACE.	Average depth in feet.	Material in which the water was obtained.	Number of wells.	Maximum flow per minute from 1 well.	Pumping capacity, 24 hours.	FOR WHOM BORED.
				Gals.	Gals.	
Burlington, N. C..	27.5	Bed of gravel.....	5	1	20,000	Aurora Cotton Mills.
Morgantown, N.C.	28.3	Decomp. gneiss...	8	1	150,000	Burke Tanning Co.
" "	39.0	" " ...	8	4	237,600	State Hospital.
" "	41.0	" " ...	5	1	100,000	Deaf and Dumb School.
Rock Hill, S. C....	56.0	" granite..	4	5	72,000	Winthrop N. and I. College
Fort Mill. " ...	35.0	" " ..	4	5	30,000	Fort Mill M'f'g. Co.
Pelzer, " ...	21.0	" gneiss. ..	4	10	100,000	Pelzer " "
" " ...	38.0	" " ...	5	1	100,000	" " "
Chester, " ...	40.3	" granite..	1	6	99,280	Gingham Mills.
" " ...	42.5	" " ..	1	2	30,000	" "
" " ...	72.0	" " ..	2	1	30,000	Catawba "
Charlotte, N. C. ..	42.0	" " ..	10	10	230,000	E. D. Latta.
" " ..	51.5	" " ..	10	$2\frac{1}{2}$	200,000	Water Works Co.
Jonesboro, " ..	31.0	" schist....	1	$1\frac{1}{2}$	5,000	Jonesboro Cotton Mills.
Reidsville, " ..	28.0	" granite..	10	1	100,000	Edna Cotton Mills.

Western Society of Engineers,

ROOMS, 1737 MONADNOCK BLOCK,

CHICAGO, ILLS.

OFFICERS FOR 1896.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

JULY 8, 1896.

Wednesday evening, July 8, 1896, the society rooms were open at 8 o'clock for the regular monthly meeting. As there were but sixteen members and guests present, only an informal meeting was held.

Mr. Thomas T. Johnston, vice president, by request of the audience, read a valuable paper on "Data Pertaining to Rainfall and Stream Flow," after which the meeting adjourned.

At the board meeting held June 23, 1896, application of Joseph Ripley for active membership was received.

At the board meeting of July 7, 1896, the following were declared elected to active membership: Edwin M. Herr, Gustav Vogelsberger, Charles S. Kaufman and James S. Stephens, and application of Charles Hilary Bell for active membership was received.

NELSON L. LITTEN,
Acting Secretary.

REGULAR MEETING—AUGUST 5, 1896.

A regular meeting (the 346th) of the society was held in the society's rooms at 8 o'clock Wednesday evening, August 5, 1896.

In the absence of the president and the vice presidents Prof. A. N. Talbot was elected to the chair. Present, eighteen members and guests. The reading of the minutes of the previous meeting was dispensed with.

Mr. Ossian Guthrie read the paper of the evening—"Relics Turned Up in the Chicago Drainage Canal." Prof. Charles H. Ford, who has devoted considerable time to investigation and study of the geologic features of the canal, was present with a number of photographic views, of a variety of peculiar formations found there, with which he supplemented his entertaining talk on the subject.

Motion to adjourn was carried.

At the board of direction meeting held July 23 the names of Mr. Joseph Ripley and Charles H. Bell were favorably reported upon by the membership committee.

The resignation of Mr. Henry Goldmark as secretary was received and accepted. Action to elect a successor was deferred until an expression of the whole board could be had.

At the board of direction meeting held August 6 Mr. Joseph Ripley and Mr. Charles Hilary Bell were declared elected to active membership.

The resignation of Mr. H. F. Baldwin was received and accepted.

After duly canvassing the question of secretary Mr. Nelson L. Litten was unanimously declared elected to that office.

The secretary was instructed to incorporate with the next published proceedings the calendar of papers to be read before the society as arranged by the committee on professional papers, which is as follows:

August 19—"Notes on Coal;" C. F. White.

September 2—"Street Pavements in Chicago;" C. D. Hill. Discussion, R. E. Brownell.

September 16—"Parks and Roads;" H. C. Alexander. "Parks and Roads;" J. F. Foster.

October 7—"Railway Yards and Terminals;" H. G. Hetzler.

October 21—"Steel for Boilers and Fireboxes;" T. L. Condron. "Steel Forgings;" H. F. J. Porter.

November 4—"Medical Treatment of Men on Engineering Work;' Dr. S. W. Maphis.

November 18—"Cableways;" Frank B. Knight.

December 2—"The Equipment of Manufacturing Establishments with Electric Motors and Electric Power Distribution;" D. C. Jackson. "Electric Traction;" Edward Barrington.

December 16—"Modern Pumping Machinery;" E. E. Johnson.

NELSON L. LITTEN,
Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid materially in completing valuable volumes for our files.

Since the issue of No. 3 of the Journal we have received the following as gifts from the donors named :

Mr. J. C. Bley—American Machinist. Vols. 12, 13, 14, 1889–90–91, complete.
Mr. W. W. Salmon—Zeitschrift Vereines Deutscher Ingenieure, Index 1884-1893.
" " " " 79 numbers, 1894–5
" " " " 52 numbers, 1895–6
Mr. Thomas C. Grier—Electrical Engineer, 16 numbers, 1896.
" World, 16 numbers, 1896
Western Electrician, 32 numbers, 1896.
Electrical Engineering, 3 numbers, 1896.
Miscellaneous publications, 20 numbers, 1896.
Janitor—Western Electrician, 66 numbers.
Electrical World, 8 numbers.
Electrical Engineer, 3 numbers.
122 other periodicals.
A Friend—10th and 11th Annual Reports Board Gas and Electric Light Commissions, Mass.
Loomis Algebra.
Chauvenets' Plane and Spherical Trigonometry.
Gummere's Surveying
Mr. J. W. Cloud—Proceedings M. C. B. Asso., Vol 30, 1896.
Librarian N. H. State Library—State Library Report, 1894.
U. S. Commissioner Education—Report for 1893–4, Vol. I, Part I.

The library and reading-room are open from 9 a. m. till 5:30 p. m., on weekdays, except Saturday until 3 p. m.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

Vol. I. OCTOBER, 1896. No. 5.

XIII.

BEDFORD-LOUISVILLE EXCURSION.

NOTES ON BEDFORD STONE, LOUISVILLE CEMENT AND OTHER THINGS.

By The Publication Committee.

Read November 2, 1896.

Many members of our society, together with friends and ladies, were fortunate in being the guests of the quarry owners in the vicinity of Bloomington, Ind., and Bedford, Ind., on the 16th of October, 1896, and equally fortunate in being entertained upon the following day by the Western Cement Company, and others, at Louisville, Ky. An inspection was made of the magnificent stone quarries on the 16th, and of the Louisville Cement Works, the "Big 4" bridge across the Ohio River and the Louisville Water Works on the 17th. The publication committee took advantage of the several occasions to make some notes of what was seen, with a view to making a record, as set forth in what follows, of the inspections made and the attendant circumstances. In this connection the committee desires to acknowledge its indebtedness to Mr. B. E. Grant, member of Western Society of Engineers, for the illustrations presented, which are reproduced from photographic negatives made by him.

Some months ago Mr. Ferd Hall, member Western Society of Engineers, chief engineer of the Louisville, New Albany and Chicago (Monon) Railroad, suggested to the entertainment committee of our society the idea of making an excursion to the Bedford stone quarries and offered his kind offices to arrange for transportation over his line of road. Subsequently a further suggestion was made that a visit should be made at the same time to the Louisville Cement Works. The time having become opportune, the suggestions were crystallized into tangible form by the committee, formal invitations having been meantime received from the several parties who subsequently became our hosts.

Those to whom our society is indebted for the many courtesies extended are as follows:

Mr. Wm. H. McDoel, V. P. and Gen'l Mgr. L., N. A. & C. Ry..........Chicago
" Ferd Hall, Chief Eng'r L., N. A. & C. Ry...................... "
" Frank J. Reed, Gen. Pass. Agt. L., N. A. & C. Ry.............. "
" Mr. J. B. Sucese, Train Master, L., N. A. & C. Ry...........Monon, Ind.
" E. H. Bacon, Dist. Pass. Agt L., N. A. & C. Ry.......... Louisville, Ky.
" W. H. Newman, Div. Freight Agt. L., N. A. & C. Ry........ "
" C. E. Worthington Pres. Consolidated Stone Co..Manhattan Bldg., Chicago
" Ed Giberson, Agt. Consolidated Stone Co. ..... " "
" M. W. Wicks Pres. Star Stone Co.....................Bloomington, Ind.
" H. A. Worley, Sec'y Star Stone Co..................... " "
" B. F. Adams, Pres. Adams Quarries.................... " "
" B. F. Adams, Jr., Sec'y Adams Quarries................ " "
" R. A. Robinson, Pres Salem Bedford Stone Co.............Louisville, Ky.
" John L. Wheat, Sec'y Salem-Bedford Stone Co.............. " "
" E. S. Walker, Supt. Bedford Belt Ry......   ....Bedford, Ind.
" J. R. Walsh, Pres. Bedford Quarries Co. and Pres. Bedford
Belt Ry...........................1st. National Bank Bldg. Chicago
" J. B. Hering, Mngr. Bedford Quarries Co..................Bedford, Ind.
" H. T. Martin, Agt. Bedford Quarries Co ..1st National Bk. Bldg., Chicago
" S. F. Runnels, Supt. Bedford Indiana Quarry, care of H. G.
Coughlen, Gen. Mngr.......................Baldwin Block, Indianapolis
" J. B. Speed. Pres Western Cement Co ....Louisville, Ky.
" Lewis Girdler, Supt Union Cement & Lime Co., care of Western
Cement Co.............................247 W. Main St., Louisville, Ky.
" J. T. Cooper, Director Western Cement Co. " " " "
" B. J. Horton, Traveling Agt. W. Cement Co.. " " " "
" Wm. Speed, care of Western Cement Co... " " " "
" Gilmer S. Adams, care of Western Cement Co " " " "
" David S. Cook, Supt. Speed's Mill, care of
Western Cement Co .... " " " "
" A. L. Kanagy, Agt. Western Cement Co..........................Chicago
Col. T. A. Courtney, Sec. & Treas. Western Cement
Co...............................247 W. Main St., Louisville, Ky.
Mr. P. A. Bonebrake, Supt. P., C., C. & St. L. R. R............Louisville, Ky.
" O. E. Selby, Res. Eng'r Louisville & Jeffersonville Bridge Co " "
" J. M. Johnson, Pres Louisville Bridge Co................. " "
" Charles Hermany, Chief Engineer, Louisville Water Co ..... " "
Capt. J. F. C. Hegewald, C. E., M. Louisville Eng. & Arch Club.. " "
Mr. Edward Mead, C. E. " " " " " "
" G. W. Shaw, C. E. " " " " " "
" Pierce Butler, M. E. " " " " " "
" J. K. Zollinger, Sec'y " " " " " "
" Marshall Morris, C. E. " " " " " "
" R. S. Ball, C. E. " " " " " "
Capt. James G. Warren, Corps of Engineers U. S. Army. Room 425
Custom House ....Louisville, Ky.
" F. VanSchrader, A. Q. M., U. S. Army................... " "
" W. T. Wood, 18th Infy. U. S. A., 211 Fourth Ave.......... " "

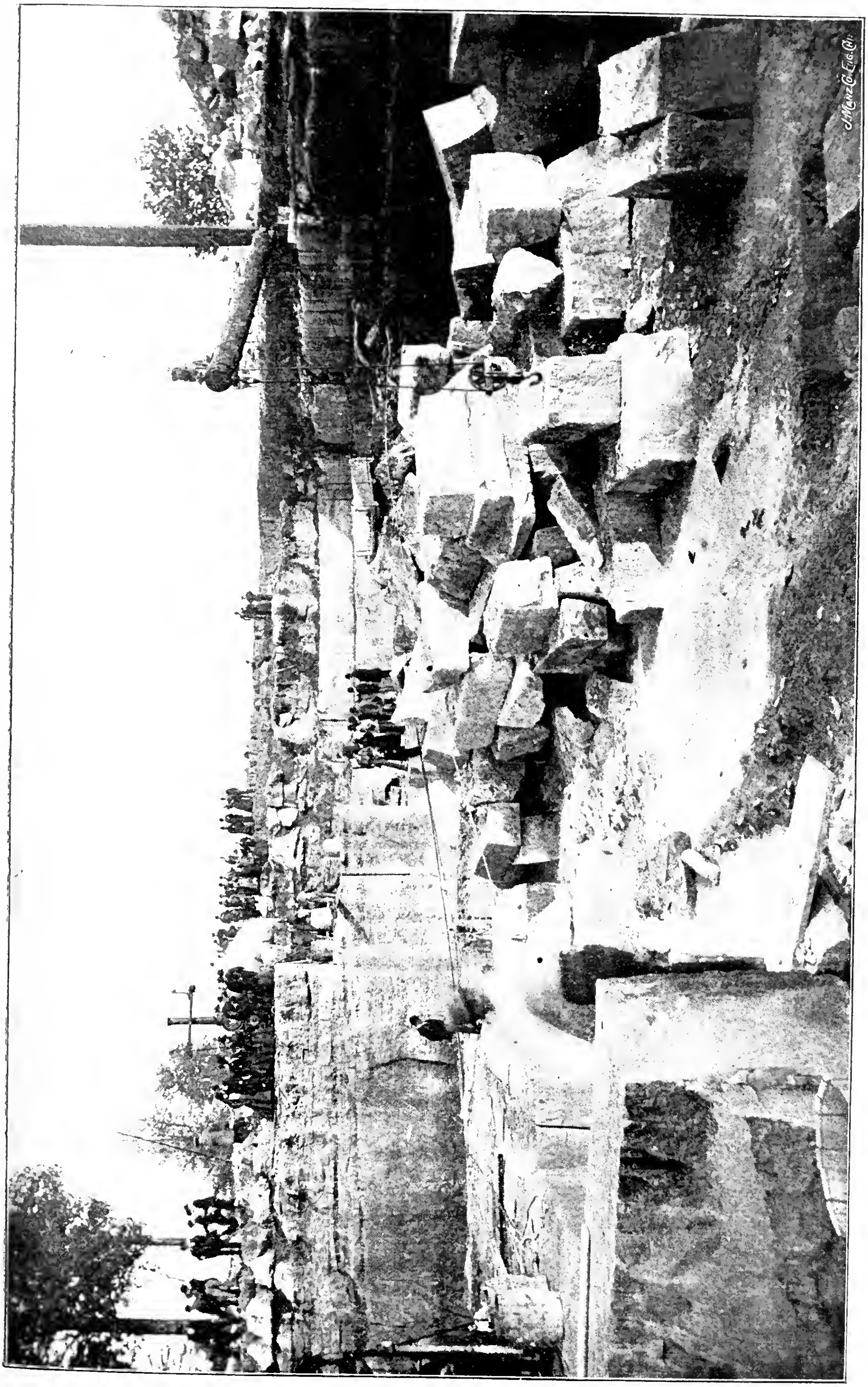


FIG. 121. HUNTER VALLEY QUARRY, NEAR BLOOMINGTON, IND.

The program finally arranged provided for the party, 175 in number, leaving Chicago in five handsome Pullman sleepers at 9 p. m. October 15, 1896, and resulted in an itinerary that will appear in what follows.

I. BEDFORD STONE REGIONS.

(a) THE OOLITIC STONE.

The geological nature and origin of the stone has been described as follows:

"The rock is an element of the St. Louis group showing itself in a massive, evenly bedded stratum of homogeneous limestone, of a whitish-gray color, whose grain, viewed casually, has the appearance of a rather coarse sand loosely cemented together. Upon careful examination with the glass, however, this grain proves to be infinitesimal shells and shell fragments all bound together by a firm and even setting of lime carbonate. No art of man could construct a mass at once so firm, even and workable, and at the same time so elastic and strong. The stone comes from the quarry soft, tough and easily cut. In a short time it hardens so that it rings with a musical note (like that from a steel bar) when struck with a hammer. A bar of four feet in length and two inches square may be bent so as to deflect greatly, and when released will spring back to a right line with the promptness and energy of highly tempered steel. Upon being broken the stone parts with a smooth direct fracture, showing a surprising evenness and continuity of texture, with no trace of laminations, seams or changes of structure.

"Geologically the oolitic limestone is very interesting, and its existence is by no means a problem easy of solution. The more it is studied, however, the more it appears to be the result of calcareous sediment deposited at the bottom of a deep trough in an otherwise shallow sea. The shells of which the greater portion of the rock is composed are, as a rule, much smaller than the smallest ordinary pin head; indeed, barely distinguishable under the most favorable circumstances by the unaided eye. These minute shells are cemented together with a cement composed of fine fragment dust of other shells and an intermediate setting of pure lime carbonate, which renders the whole mass perfectly homogeneous, elastic and resonant."

The stone is found in southern Indiana on the line of the Monon (L., N. A. & C. R. R.) through a distance of nearly sixty miles, say from Salem northwesterly to the west branch of the White River where the Monon crosses the Indianapolis & Vincennes R. R. Salem is about thirty miles northwest of Louisville, Ky.

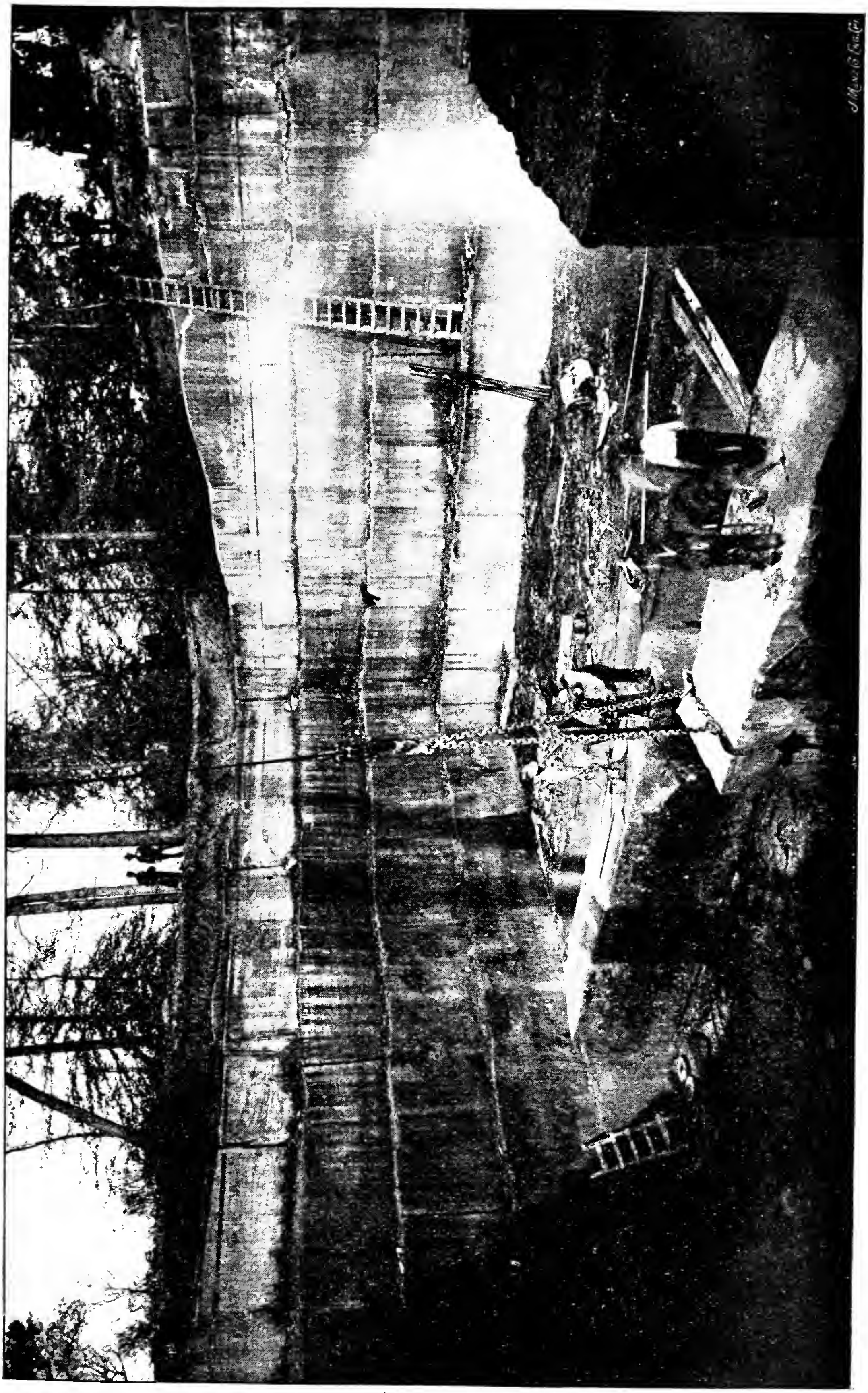


FIG. 122. STAR QUARRY, NEAR BLOOMINGTON, IND. WEST END.

The utility of the stone for engineering structures is of more immediate importance. The crucial test of experience, as stated elsewhere, has extended over a period of about seventy-five years as far as its use in structures is concerned. Its extensive use at places remote from the quarries indicates its general superiority to other stones, durability and cheapness being prime elements involved.

Detached blocks are found at the vicinity of the quarries which apparently have stood the test of ages without deterioration.

The texture is variable, and in good merchantable stone varies in appearance from a very fine to a very coarse sand, and the texture may vary between these limits without materially affecting durability or strength. In color there is the distinctively buff and blue, both of light shade. No explanation has yet been made of the reason for the two colors. They are often seen in one and the same block, the line of demarcation between them being radically well defined, the color changing while the quality of the stone remains the same. Among the quarrymen color is regarded as affecting the appearance of the stone only, though some authorities regard the blue stone as being generally the harder and more resisting. In the quarries the blue underlies the buff, but there is no uniformity in the thickness of either. In some quarries the blue is absent, or nearly so, while in other quarries near at hand it is nearly all blue.

The thickness of the stone deposit, which in some places is as much as sixty feet, is variable, due in part at least to erosion of its upper part. It is covered with a layer of earth of variable thickness, but generally but little at the quarry sites. The top stone for a few feet in thickness, called bastard stone, is classed with stripping, but, as shown in Figs. 122 and 123, at the Star quarry, it may be of little importance.

The resistance of the stone, as far as the elements and strength are concerned, and also the chemical constitution, are stated clearly elsewhere.

The facility with which the stone can be shaped is well illustrated by the several views of the stone on machines at the mills. It can be planed into any shape involving simply straight lines, or turned in a lathe into shapes having circular cross-section. It seems about as susceptible to the action of a tool as is wood.

Nature has not made all stone perfect, nor has it made all oolitic or Bedford stone perfect. While enormously extensive parts of the deposit may be of sterling quality there are still other parts that are quite imperfect. There are a number of characteristic defects. The dirt seams shown in Fig. 138 concern the quarryman more than the engineer, for, while the adjacent stone may be good enough, they involve bad shaped blocks and much waste. The quarryman may also find localities where the stone refuses to break evenly, thus defeating desirable shapes and involving difficult working. At other localities the stone may not have its component shells sufficiently cemented, or the stone may be too coarse, with frequent

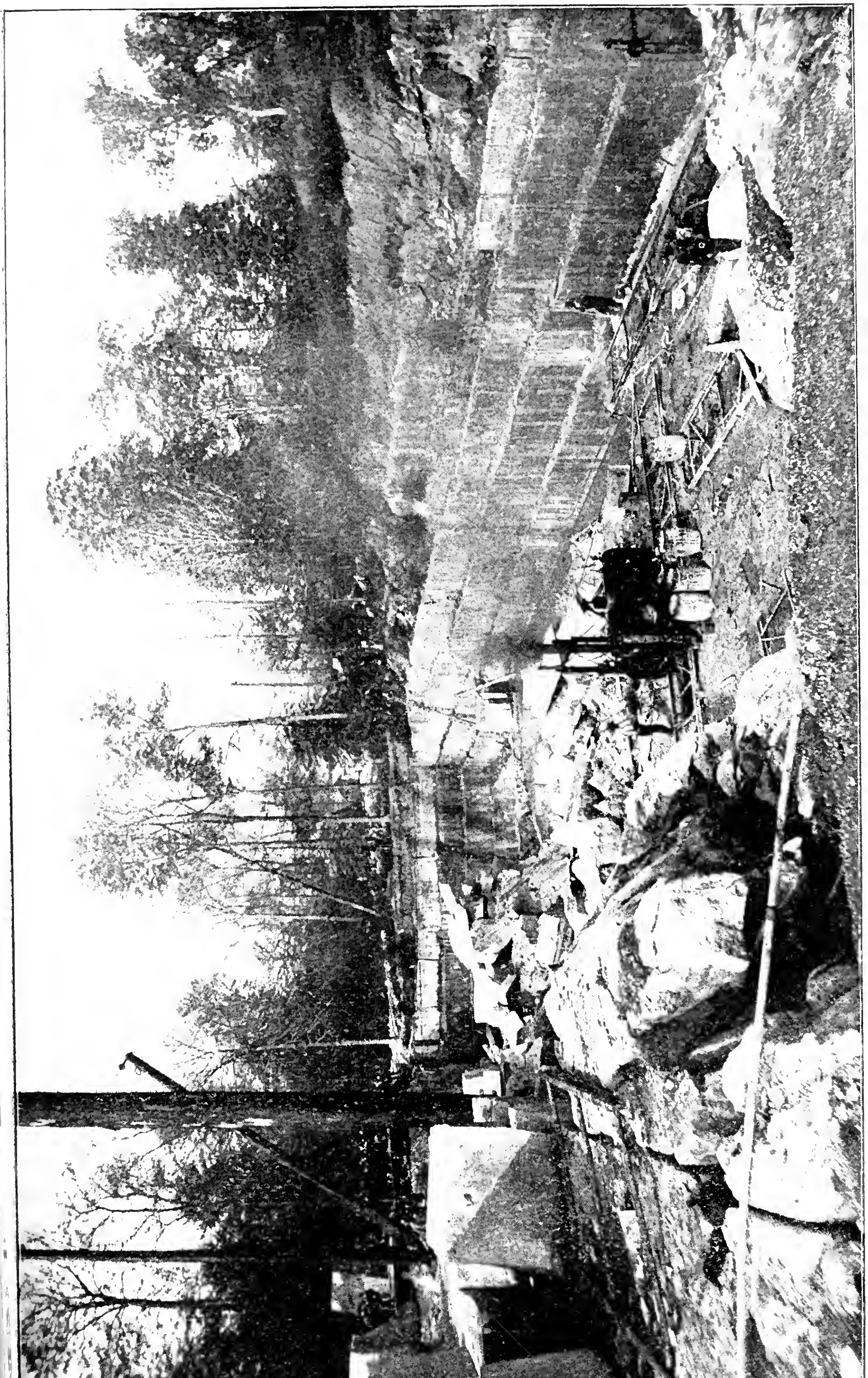


FIG. 123. STAR QUARRY, NEAR BLOOMINGTON, IND. LOOKING WEST.

shells. There are also pebbles, silica sacks, crowfeet and glass seams, and unsightly variation of color. The influence of these defects depends largely upon the purpose for which the stone is to be used. While some of them do not affect durability they may affect strength, or perhaps affect appearance only. The engineer may, however, so draw his specifications as to essentially avoid all these defects and be assured that there need be no difficulty in obtaining all the stone he may desire. Among other things he would do well to visit the quarry from which he will take his stone.

If appearance is to be a factor in a finished structure the use of hydraulic cement should be avoided because it has the effect of badly discoloring the stone adjacent to the joints. There are special cements made, too expensive or not suitable for general work, with which stones may be cemented together. Sometimes, when finished stones are marred by a dog hole, or otherwise, a crafty quarryman will plug the hole with a small piece of stone, using this special cement for the purpose. It might be well to specify against plugged stones.

The time of quarrying is important, since the stone in places is impregnated with what is termed quarry sap, and such stone, if not duly seasoned before being subjected to low temperatures, will crack on being frozen. The period required for seasoning is variable, but generally several weeks. A stone taken from a part of the quarry long exposed requires less time, but taken from newly exposed parts requires more time. Once properly seasoned, however, the action of frost is not to be feared.

The effect of seasoning is to improve the resistance of the stone as to strength, and hardens the stone, though not to an extent that materially affects the facility with which a stone may be shaped.

The wide expanse in which the stone occurs gives unbounded opportunity for opening quarries, and the nature of the deposits is sufficiently variable to render problematic the merit of a quarry until it is well developed. On this account the engineer should take some trouble to become acquainted with the quarry from which he receives stone. In fact, he should visit it with a view to learning the probability that may exist as to whether he will at all times receive suitable stone.

In that which follows is given two abstracts from the "Second Report of the Board of Capitol Commissioners of the State of Georgia," 1886, which are interesting as setting forth the results of their examination into the merits of the stone in question.

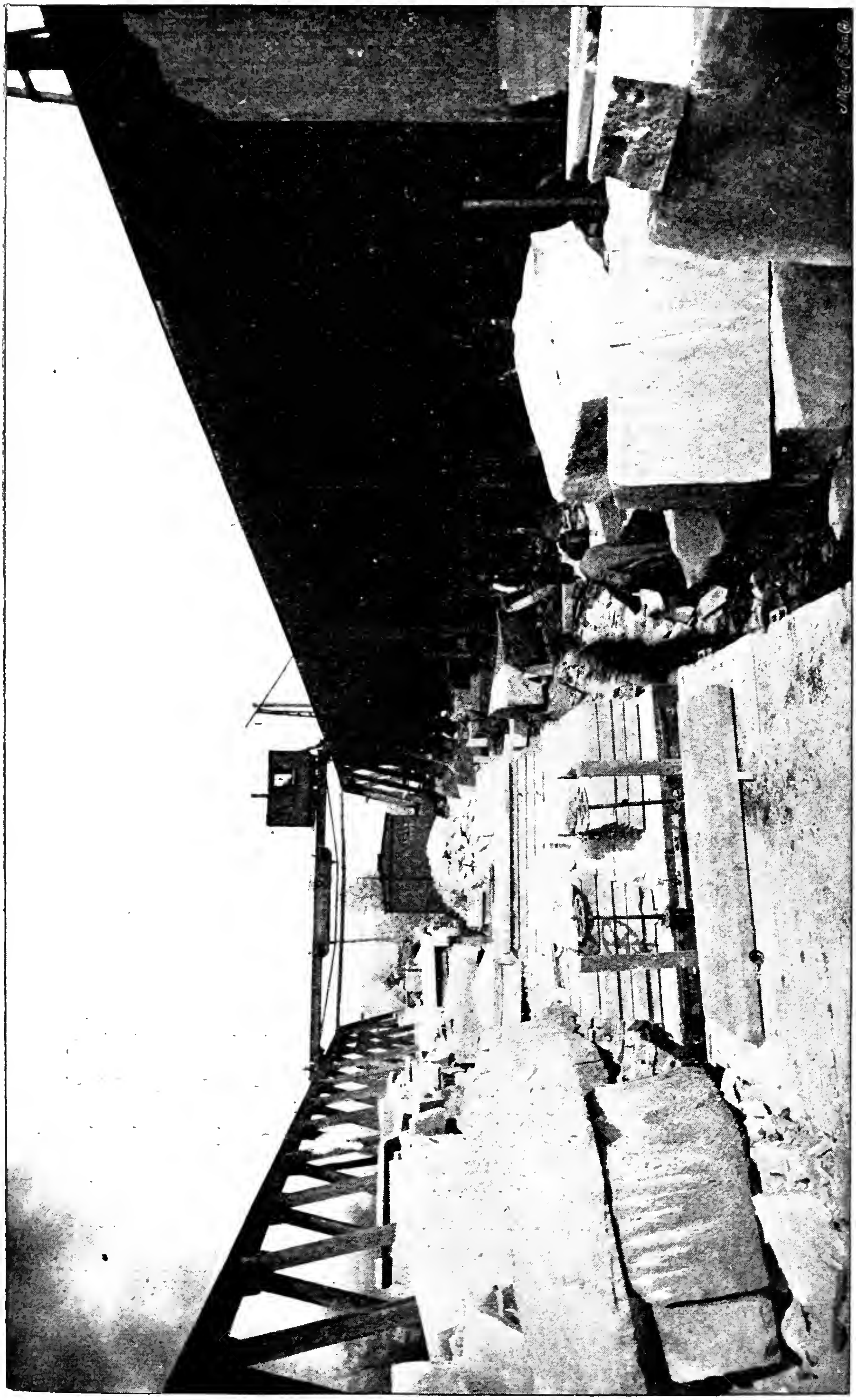


Fig. 124. Consolidated Stone Co., Mill Near Bloomington, Ind. Machine Shed.

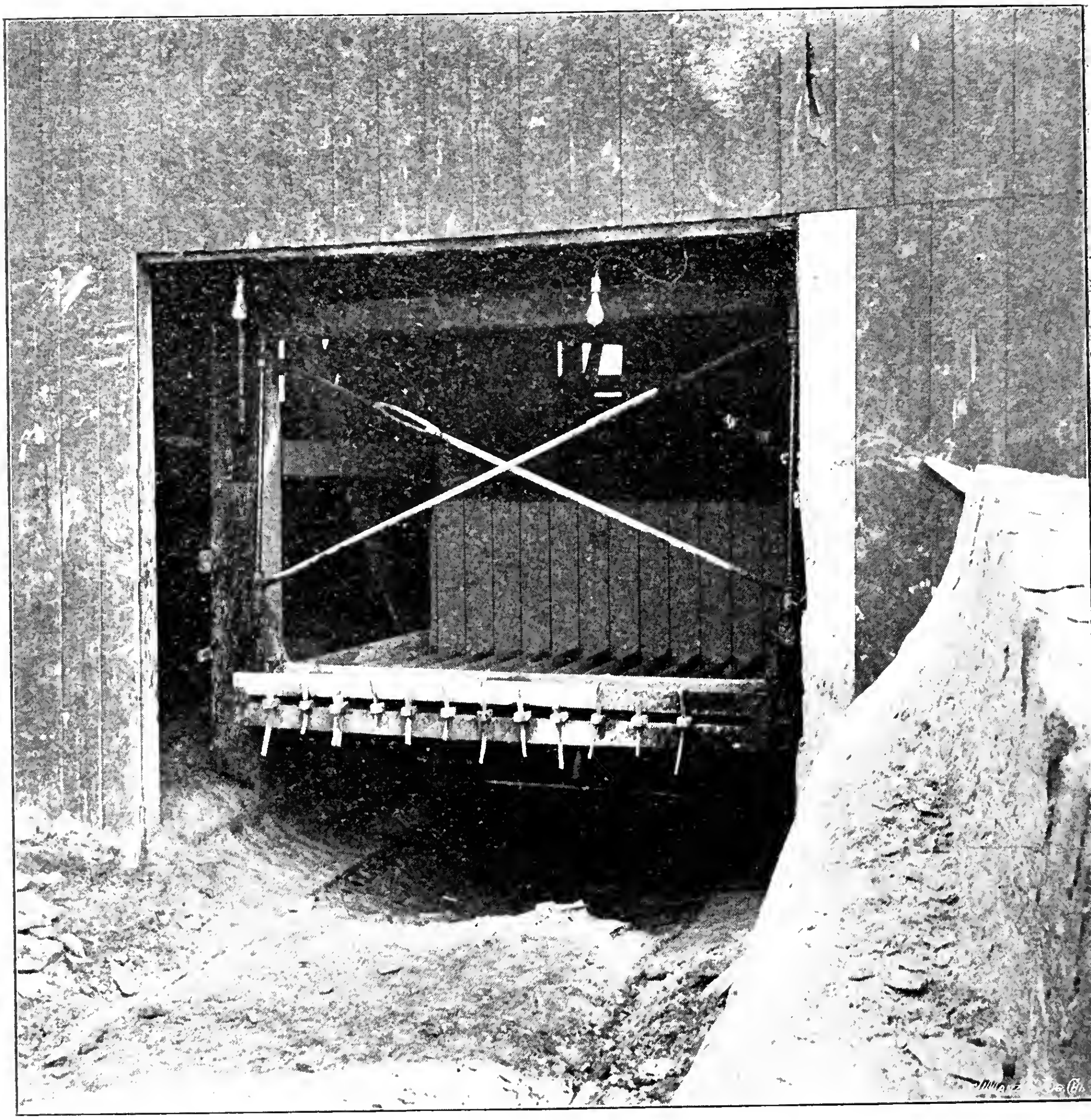


FIG. 125. CONSOLIDATED STONE CO., NEAR BLOOMINGTON, IND.
SET OF SAWS.

Office of the Capitol Commission,
Atlanta, Ga., September 1, 1885.

To the Senate Committee on Public Property:

Gentlemen—In response to the invitation of your honorable body to the Board of Capitol Commissioners to submit any comments upon the testimony taken by your sub-committee, recently printed for the use of the Senate, the Board respectfully submits the following:

The testimony as published bears almost entirely upon two questions—

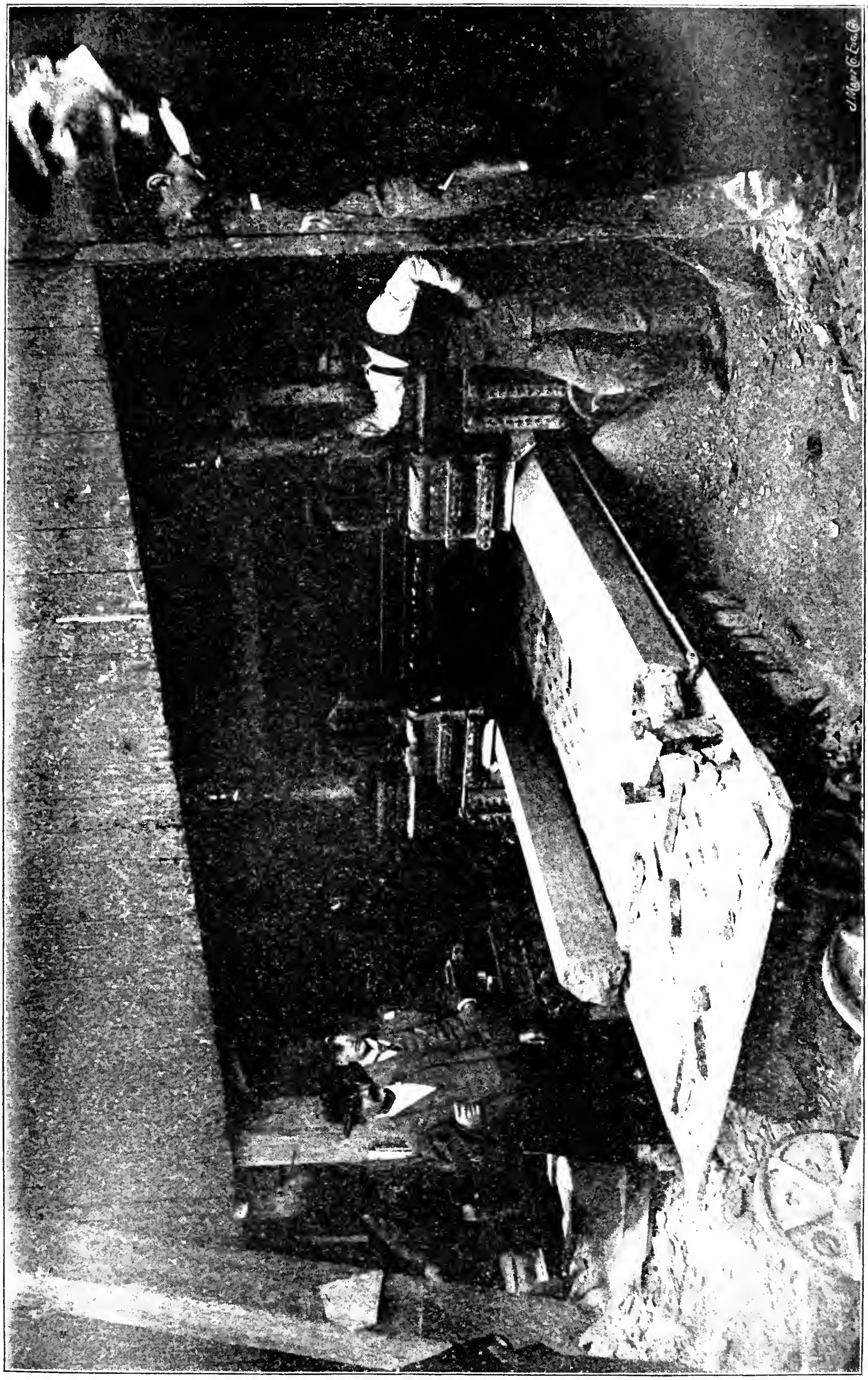


FIG. 126. CONSOLIDATED STONE CO., NEAR BLOOMINGTON, IND. A PLANER.

1. What is the comparative cost of building the capitol of granite or marble and the cost of building it of oolitic limestone?

2. Has the oolitic limestone adopted by the Commission the requisite qualities of strength and durability?

As to the cost of marble as compared with that of the oolitic stone the witnesses all agree that it will be "very much greater." Eighty cents per cubic foot for the quarry blocks is the lowest price suggested as possible by any one. The printed testimony of Mr. Clements at one place and of Mr. Clark at another speaks of thirty cents as perhaps possible, but these are supposed to be misprints for eighty cents, as no bid lower than that ever reached the commission. And Mr. Clements' testimony elsewhere is, that even $1.00 would be an extremely low figure for good marble.

The oolitic limestone is delivered at fifty-five cents.

Next, as to the cost of working the stone, the witnesses examined by the sub-committee speak of it as very much greater, but without giving exact figures. The contractors, Messrs. Miles & Horn, estimate this expense in an official letter heretofore communicated to the Senate at sixty cents per cubic foot for oolitic and $2.00 for marble. This makes marble $1.65 per cubic foot more than oolitic limestone, and on 123,610 cubic feet, the increased cost would be about $204,-000.

None of the testimony taken is at issue with these figures. It must be clear, therefore, to every member of the committee that the Commission could not possibly have contracted for a building of the size and style and character of finish which they have adopted (considering it the best of all the plans submitted) out of marble or granite with the means at their disposal, but would have had to cut it down so enormously in some respects as to seriously impair its dignity and suitableness for the purposes intended.

Under the Act imposing their duties the Commissioners would not have been justified in this course, unless the cheaper material lacked the necessary elements of strength, durability and beauty.

This brings us to the second question raised by the testimony taken by the sub-committee, and here the Commission takes direct issue with every witness who impeaches the character of the oolitic stone in either of these respects, and is prepared to refute every charge with evidence of higher character than that brought against it. Indeed, that brought against it, upon examination, will be found to be of the weakest character. Scarcely any of the witnesses pretend to have any exact personal knowledge on the subject. We will show that some of them really know even less than they thought they did. Professor Pratt, for instance, has examined a stone "said to be" from the Salem quarries, and found it to absorb four and one-half per cent. of water. On this single fact he assumes that the stone will not be durable as compared with marble. Professors Rankin and Mahan, who are better authority, say that the absorption of water is no test between stones of different structure. A magnesian limestone, for instance, may absorb less than one per cent. of water, and a good

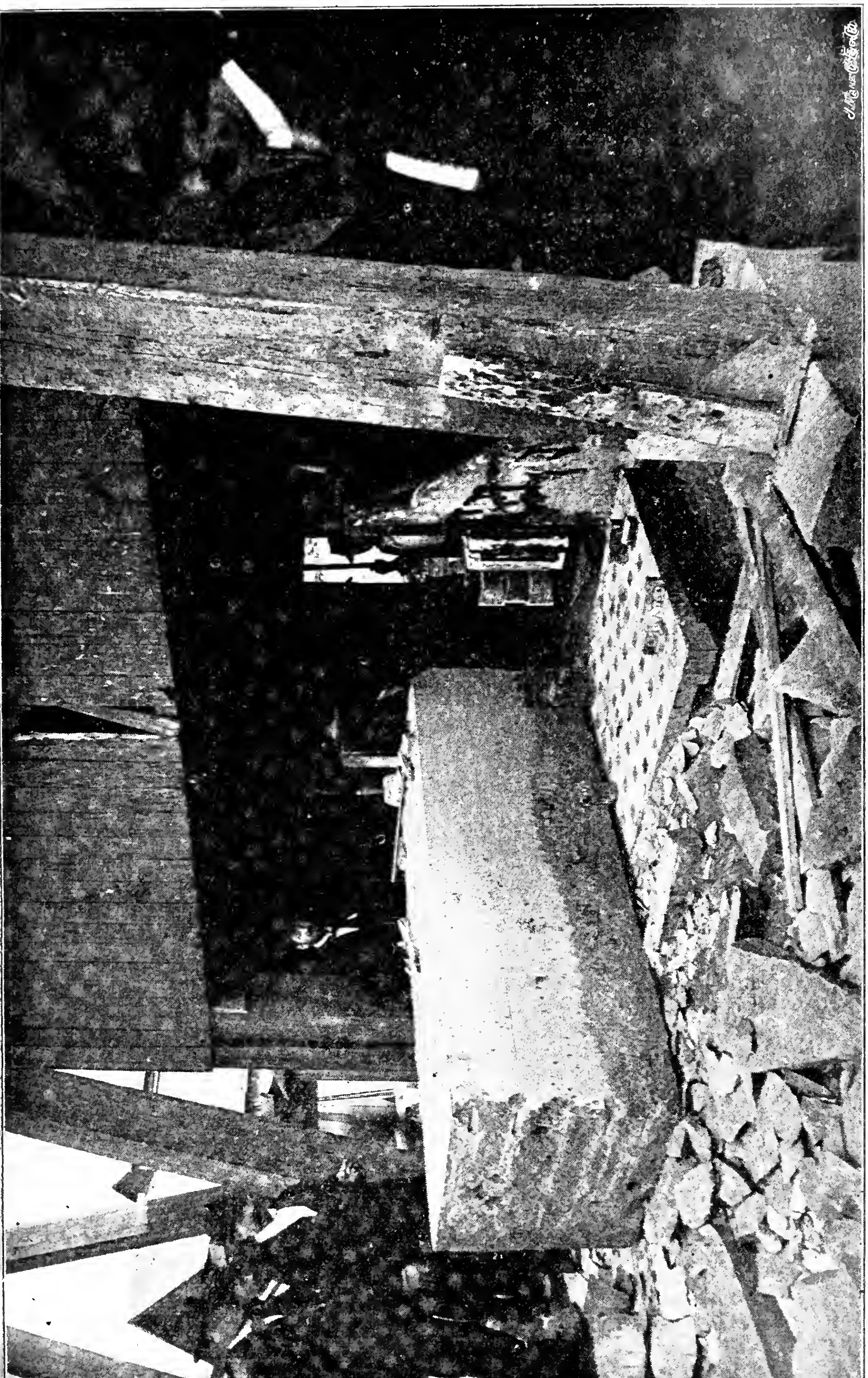


FIG. 127. CONSOLIDATED STONE CO., NEAR BLOOMINGTON, IND. A HEADER.

brick perhaps forty per cent. Yet the magnesian limestone will discolor, exfoliate and decay rapidly, while the brick will last a thousand years.

Two instances are pretended to be given of oolitic limestone buildings decaying—the Dime Savings Bank, of New York city, and the Cooper Institute. A letter from the curator of the Cooper Institute submitted herewith states that this building has not deteriorated, and moreover it is not built of oolitic limestone, but of a brown sand stone. The Dime Savings Bank is said to have deteriorated, but it is built of marble from the Snowflake quarry of West Chester county, New York. (See Vol. X Tenth Census, folio 324.) A quarry, too, which had previously furnished much good building stone. This fact suggests that marble quarries are not always uniform in their quality, and many instances of marble, not only discoloring, but exfoliating or decaying rapidly, can be pointed out.

But the Commission has no desire to question one word of all that is or may be asserted in favor of any of the Georgia marbles. That material is simply "put out of court" by its cost. We only wish to assure the committee that even apart from all questions of economy, the Commission has not acted hastily or unadvisedly in their selection of material, and we append hereto the documents in support of this statement.

Salem stone was selected by the Commission in the belief that when strength, beauty, durability and cost are considered, it was the best material offered by the Board, and we have been strengthened in that conviction in every way since the selection was made.

It possesses the most remarkable uniformity of grain and texture, is exceedingly bright and handsome in color, can readily be worked in any shape, is peculiarly suited to the design we are carrying out, is less liable to discolor than almost any other stone of so light a color, and the evidence from witnesses qualified to testify is that its durability is equal to that of any stone in the world.

For the purpose of becoming familiar with the constituency and physical properties of this stone, the Commissioners have had it subjected to chemical analysis and some mechanical tests, the results of which are herewith reported.

The chemical analysis of Salem stone is:

Carbonate of lime	96.04	per cent.
Carbonate of magnesia	0.72	per cent.
Oxides of iron and alumina	1.06	per cent.
Insoluble silicates	1.13	per cent.
Chlorides of soda and potash	0.15	per cent.
Water expelled at 212 deg. F	0.10	per cent.
Combined water, etc.	0.80	per cent.
	100.00	

This analysis was made in the office of the Georgia State Chemist, and agrees with all the published analyses within very close limits.

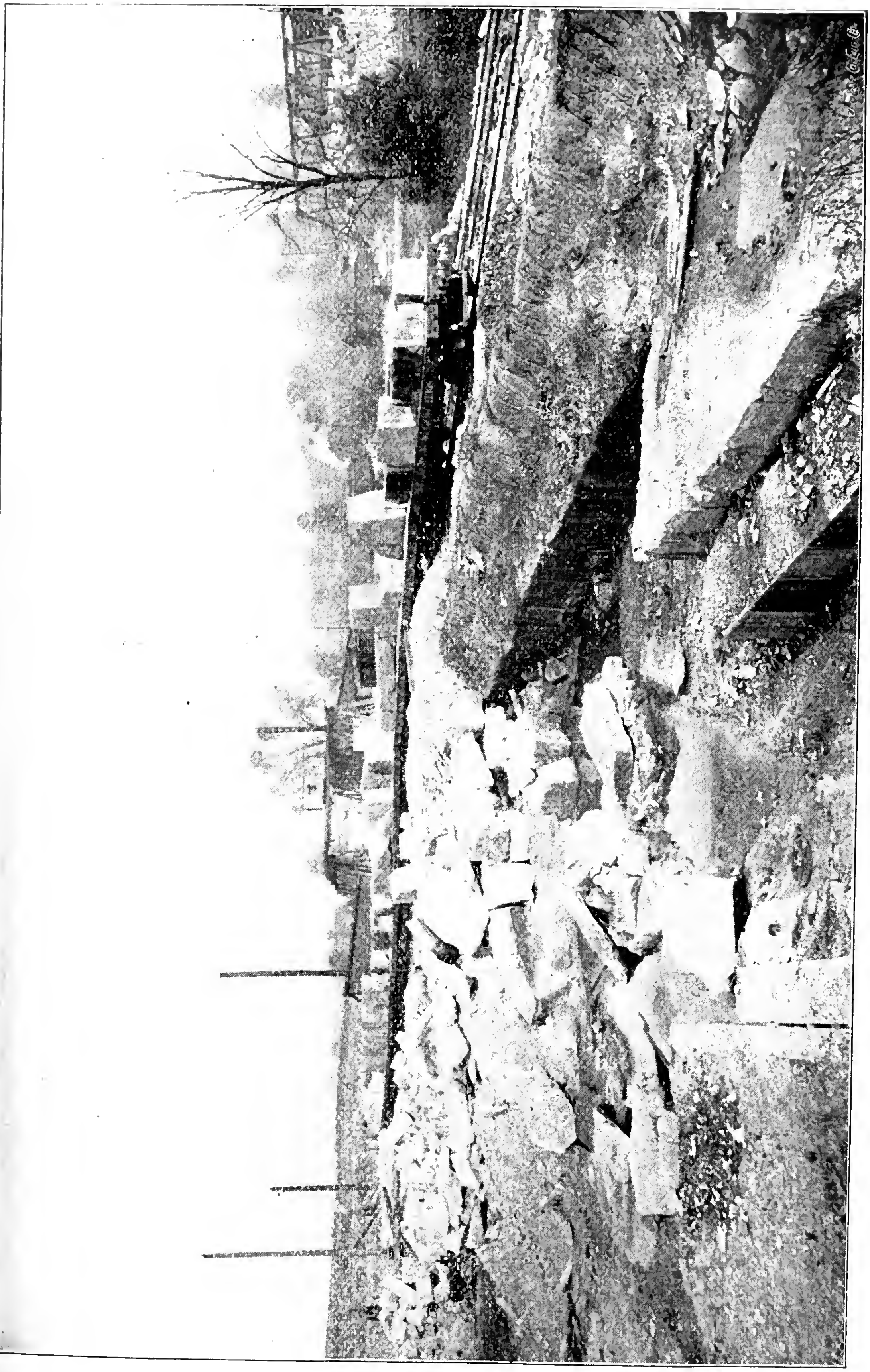


FIG. 123. CONSOLIDATED STONE CO., NEAR BLOOMINGTON, IND. TRAIN LOAD OF MILL BLOCKS.

As to its capacity to resist heat, we had a small block of this stone heated in the office of the State Chemist in a cupel furnace to a temperature of 1200 deg. F. without injury to the stone.

We have also a sample which has been frozen for four hours and shows no sign of injury whatever.

Mr. Champayne, the Superintendent of the capitol, and a bonded and sworn agent of the State has made careful tests of its absorption of water on a random specimen, and finds it to absorb water in the ratio 1 to 42 or 2 38-100 per cent.

Colonel L. H. Charbonnier, Professor of Physics in the University of Georgia, certifies to the Board that he has tested the stone for strength in a Richle testing machine, and finds a resistence of 8,975 pounds per square inch. This strength is less than that shown by General Q. A. Gilmore, and by the Indiana geological reports, which state it at 11,750, and 10,000 to 12,000 respectively, and the difference is due to the fact that the sample tested for the Board was a freshly cut specimen, and had not become indurated by exposure, as was the case in the samples tested by the authorities noted. The greatest weight upon any stone in the capitol building is estimated to be less than 90 pounds per square inch.

These experiments and tests indicate an excellent stone, and the use of it, on the evidence of this data, might, perhaps, be warranted; but the most direct evidence of its durability and other good qualities is obtained from other sources.

Professor Newberry, after enumerating the various tests to which building stones have been subjected, says: "All these tests are of little value, as compared with an examination of the natural outcrops of the rock." Says Mahan, in his text-book on Civil Engineering: "The chemist and geologist have not laid down any infallible rules to guide the engineer in the selection of a material that may be pronounced durable; the best indication may be obtained by an examination of any rocks of the same kind, which are known to have been exposed for a long period."

Prof. Rankin, one of the very highest authorities, in his work on Civil Engineering, says, "the only test of the durability of any kind of stone is experience."

Dr. Julian, special agent of the 10th census, says, "the only safe test is the careful observation of results in cases of actual construction, or failing in that, the observation of the weathering of the stone in its natural deposit."

We might quote other authorities to show that experience is the only safe test, but these we deem sufficient, as we are very sure that the estatements of any number of experts that a given stone will, in their opinion, fail, is of very little value when brought face to face with the robust fact that that particular stone does, in many cases tried, has never yet failed.

The witnesses who appeared before the sub-committee had, for the most part, no practical experience, either in use or observation of this stone, but the Commissioners have been more fortunate in

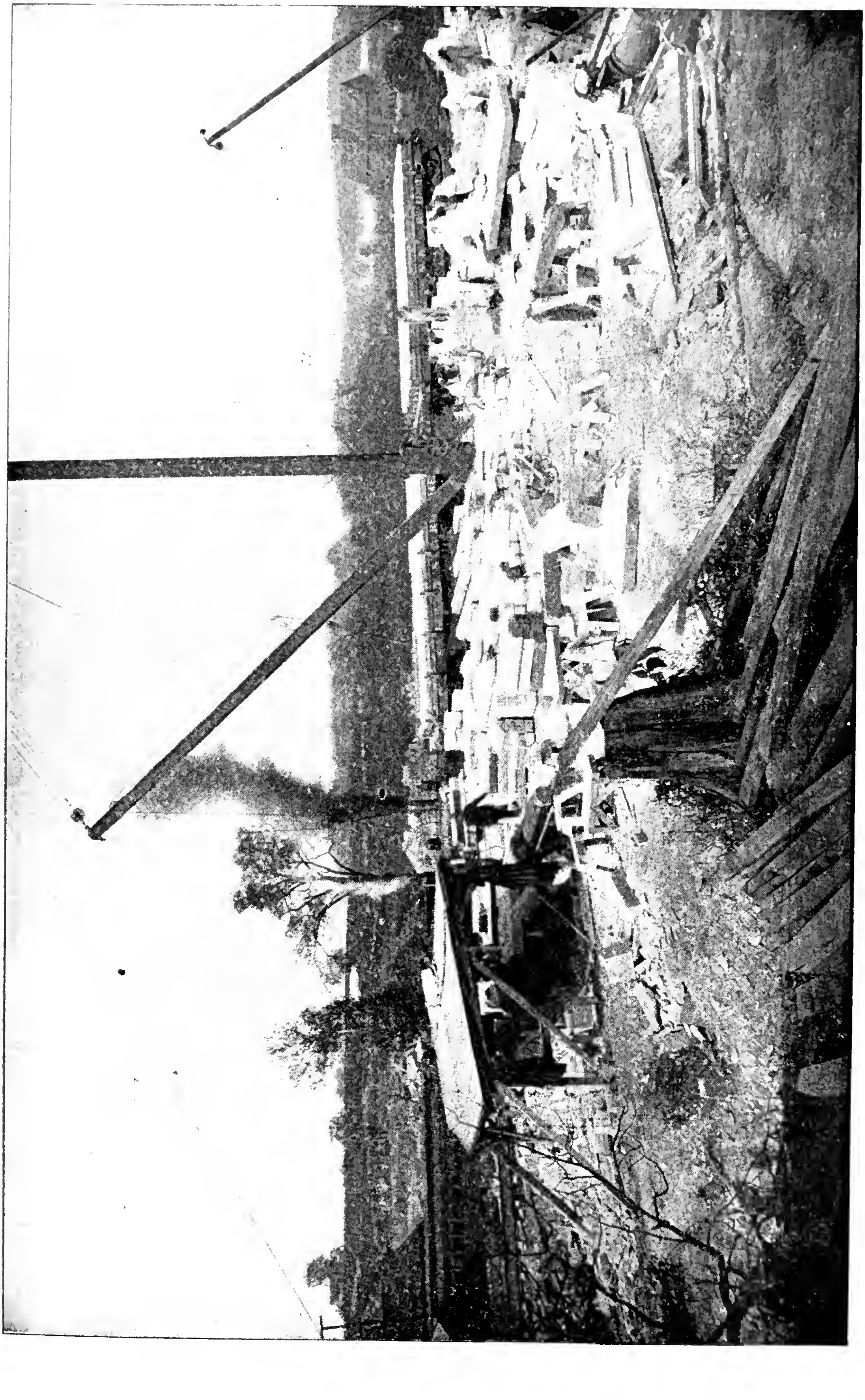


FIG. 129. CONSOLIDATED STONE CO., NEAR BLOOMINGTON, IND. STONE-CUTTING YARD AT MILL.

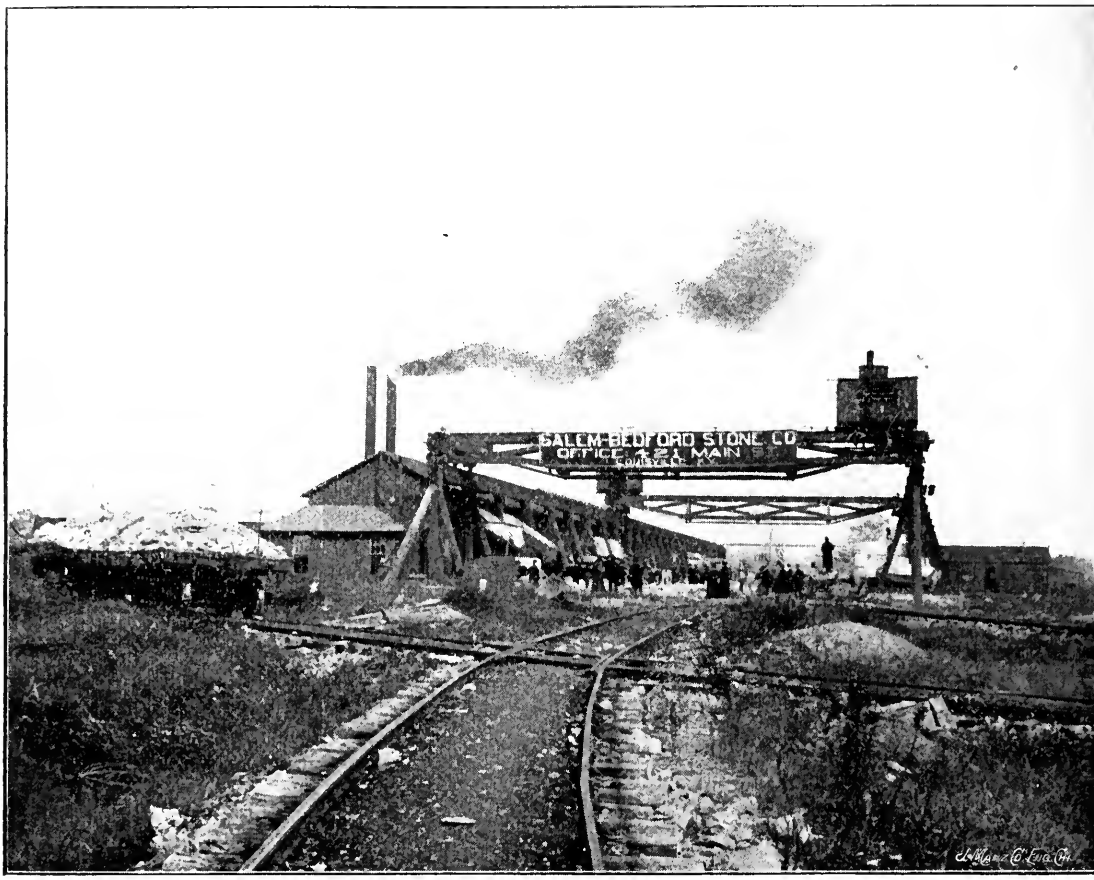


FIG. 130. SALEM-BEDFORD STONE CO., NEAR BEDFORD, IND. THE MILL.

their investigations, and present herewith the statements of parties who have used and observed the Indiana oolitic limestone, and we make the assertion, without fear of contradiction, that there is no case on record of its failure from this or any of the other quarries producing it. The amount of this stone quarried and sold in the State of Indiana has steadily grown from less than 2,000,000 cubic feet in 1880 to more than 6,000,000 cubic feet in 1884, a record which shows beyond cavil the popularity of it and its growing appreciation by builders everywhere.

We quote here from various parties as follows:

Mr. Jno. Collett, State Geologist of Indiana: "The striae and erosions of the glacial age are seen, dating back to the beginning of quaternary time. This stone has withstood the elements and their disintegrating action during these long periods, and can be confidently recommended for the erection of extensive and permanent structures."

Professor E. T. Cox, his predecessor in office, says: "Examined along the crop, this stone shows a wonderful resistence to weathering. As a durable building stone, it has withstood the ravages of

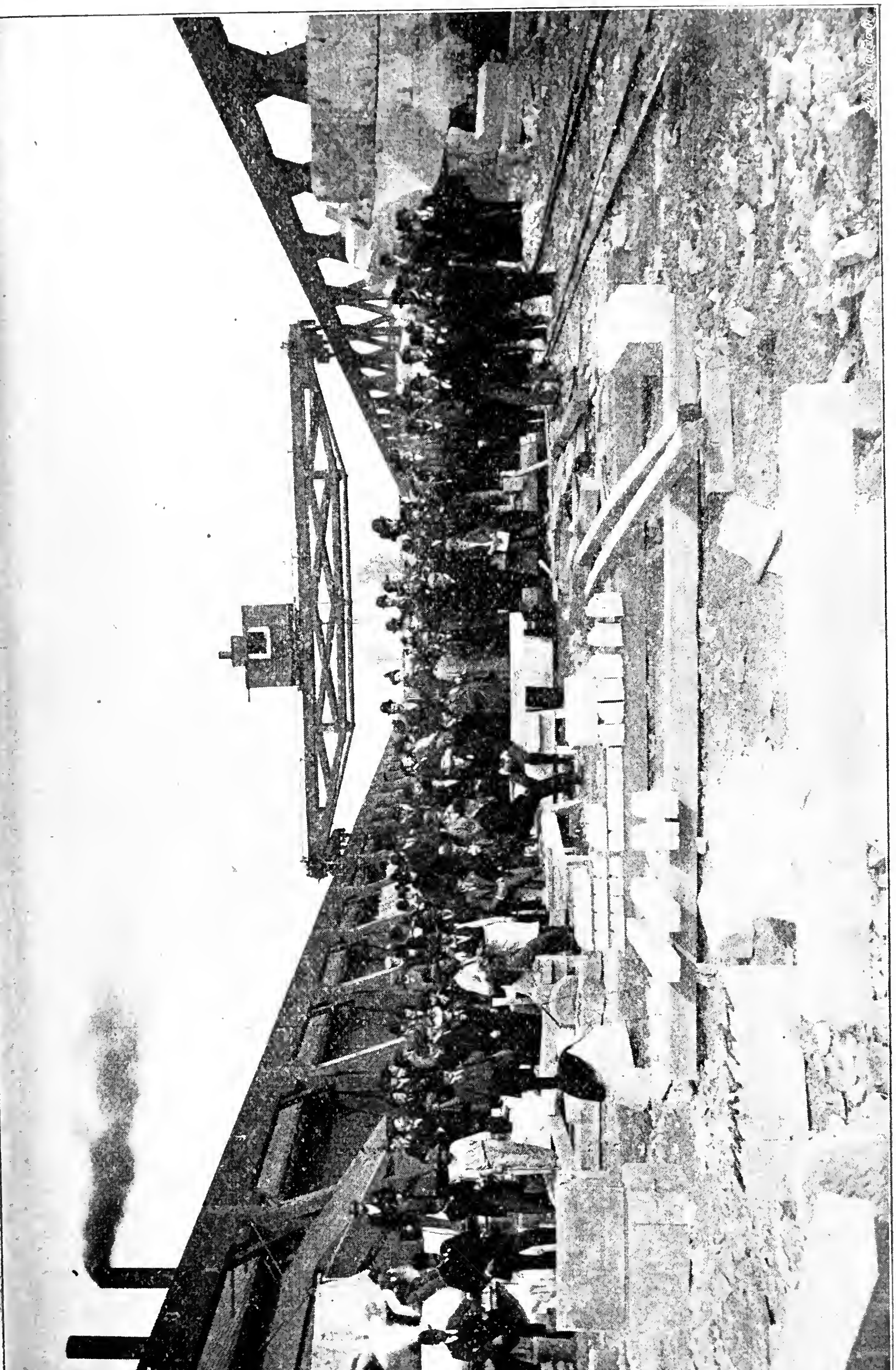


Fig. 131. Salem-Bedford Stone Co., Near Bedford, Ind. Yard at Mill.

time in buildings for upwards of fifty years, and still retains the hammer and chisel marks almost as sharp as when cut."

Indiana Geological Report for 1882: "In natural outcrop it presents bold,perpendicular faces to the elements, showing every scratch and mark, unaffected after the exposure of thousands of years, as no other stone or rock does."

Idem: "Here there is presented to the builder and architect a new and wondrous element, in an elastic stone, a potent quality, which, united with its other sterling excellencies of strength and beauty, makes Indiana oolitic limestone the best in the world for exposed work in buildings in localities subject to great climatic changes."

Idem: "It has been, and is now, being used in many of the finest public structures in the country. The new $2,000,000 court-house at Indianapolis, the new Indiana State House, the post-office, and many churches in that city; the Custom House at Louisville, the City Hall and water tables at Lincoln Park, Chicago, many fine structures in St. Louis, the Cotton Exchange in New Orleans, many public and private buildings in New York and Philadelphia and the exposed part of the new State House of Illinois."

If the Salem stone is so worthless, it would seem to be an easy matter to point out instances of its failure. As no such cases are cited, and it has stood so many tests of experience and actual use, and is so highly indorsed by all who have either used or examined it, the Commissioners respectfully submit that the evidence, as a whole, is irresistibly conclusive that there can be no question this material is in every way worthy of confidence as a strong, durable and beautiful material.

HENRY D. M'DANIEL,
Governor and Ex-Off. Chairman,

PHILIP COOK,
E. P. ALEXANDER,
W. W. THOMAS,
A. L. MILLER,
EVAN P. HOWELL.

Office of the Board of State House Commissioners,
Indianapolis, Ind., August 29, 1885.

To the Editor Atlanta Journal:

Dear Sir—The oolitic limestone of the Salem quarries is well known to the Board, having been thoroughly examined by them, as well as the stone from other quarries, before letting the contract for the new State House. What is said of one quarry of the oolitic limestone of Indiana may properly and truly be said of all of them. They are of the same geological formation, and the chemical composition is remarkably uniform, being almost a pure carbonate of lime.

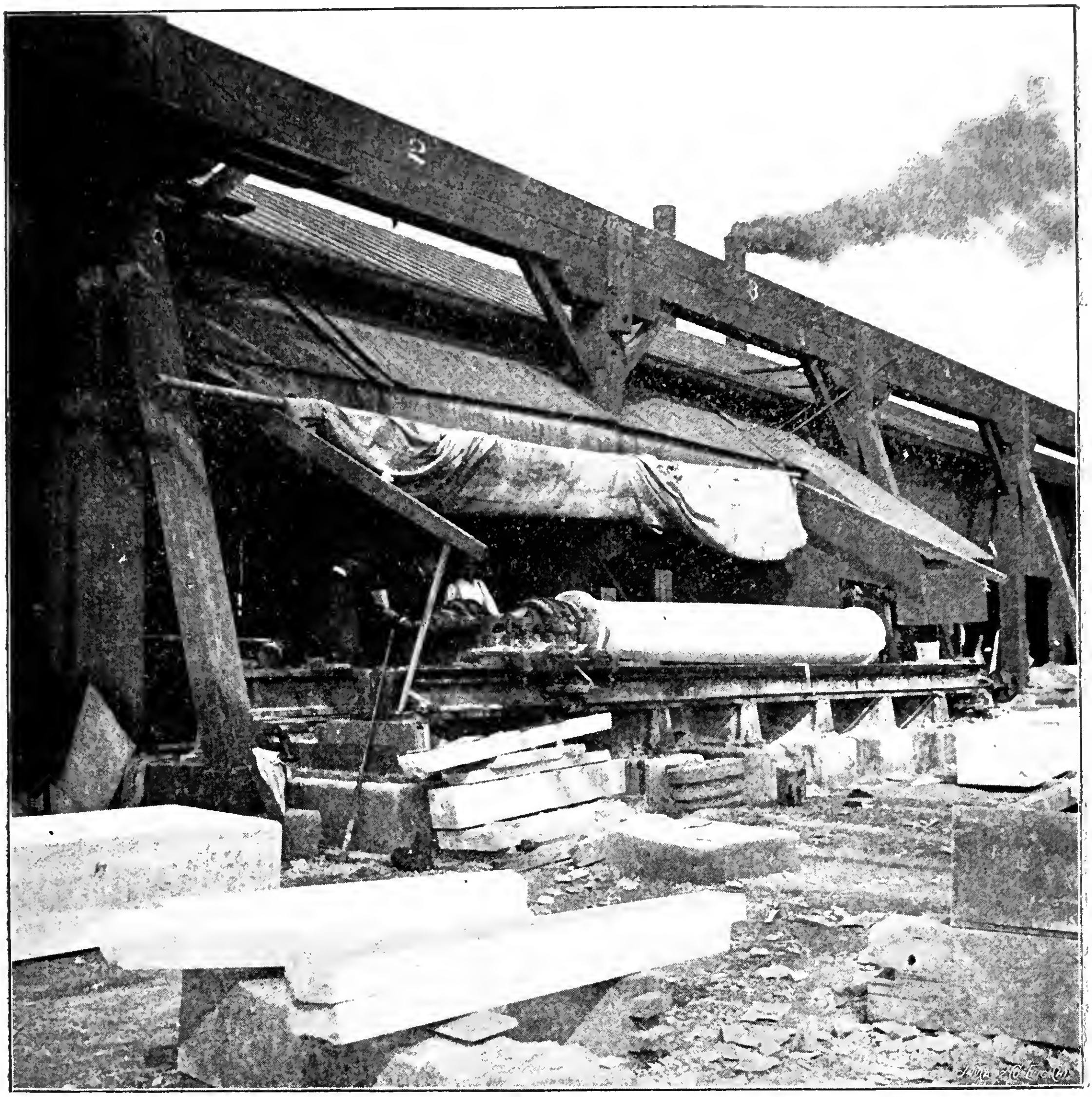


FIG. 132. SALEM-BEDFORD STONE CO., NEAR BEDFORD, IND. TURNING-LATHE AT MILL.

There are many buildings in this and other States built in part or wholly of this stone. It did not come into use except in a local way near the quarries. The oldest building examined by us, in which this stone was used, is the Court-house at Bloomington, Indiana, erected sixty-five years ago. This is a brick building with stone trimmings about the doors and windows; the finish of the stone is the kind known as "droved" work, which work has been extremely well done originally, and is absolutely perfect to-day. The stone shows no sign of "weathering off" in the most exposed places. The arris of all exposed stone is perfect, and the "droved" surface looks as well to-day as when first done. The temperature at this place sometimes reaches twenty-five degrees below zero.

In our examination of the various quarries, we often found places where immense masses of stone, at some remote period, had been broken off from the main ledge. We could discern no debris or signs of decay; projecting parts presented sharp corners, as though the fracture was recently made, when, in fact, it may have been thousands of years ago.

We have in Indianapolis a large number of buildings in which this stone is largely used; in fact, we may say that no other stone has been used to any extent for the past thirty years. We do not know of a single case or instance where the stone has not given entire satisfaction, and know of no case where it shows any signs of decay.

The only conditions that we have discerned necessary for the successful use of this stone is that it should be quarried some weeks before it is subjected to a hard freeze, so that the "quarry sap," as it is called, shall have partly left. No amount of soaking in water afterwards makes it liable to be injured by frost, as has been proved by repeated trials. These conditions apply, so far as we know, to almost or quite all the building stone in use.

The following analysis is given as a sample of a large number made to determine the component parts of the Indiana oolitic limestone:

	Per cent.
Water dried at 212 degrees F.	0.35
Insoluble silicates	0.50
Ferric oxide and alumina	0.98
Lime	54.10
Magnesia	0.13
Carbonic acid	42.62
Sulphurous acid	0.31
Chloride of alkalies	0.40
Combined water and loss	0.61
Total	100.00

Lime 54.10 equals carbonate of lime 96.60. Tests were also made of the crushing strength, ratio of absorption, etc. These tests show an average strength of 10,000 to the square inch, and a ratio of absorption of one to thirty.

The greatest weight on the foundations of any building now known is 45 tons to the square foot. It will be seen by calculation that this stone will safely carry a load of twice this amount. If, then, the stone is durable, and will safely sustain all the possible load that may be placed upon it, it only remains to be shown, to place it in the front rank of all the building stone in the United States, its cheapness and the facility with which it may be fashioned into any desirable shape. It will receive the most elaborate carving, with a depth of cut and a delicacy of design that is equaled by no other stone. These latter

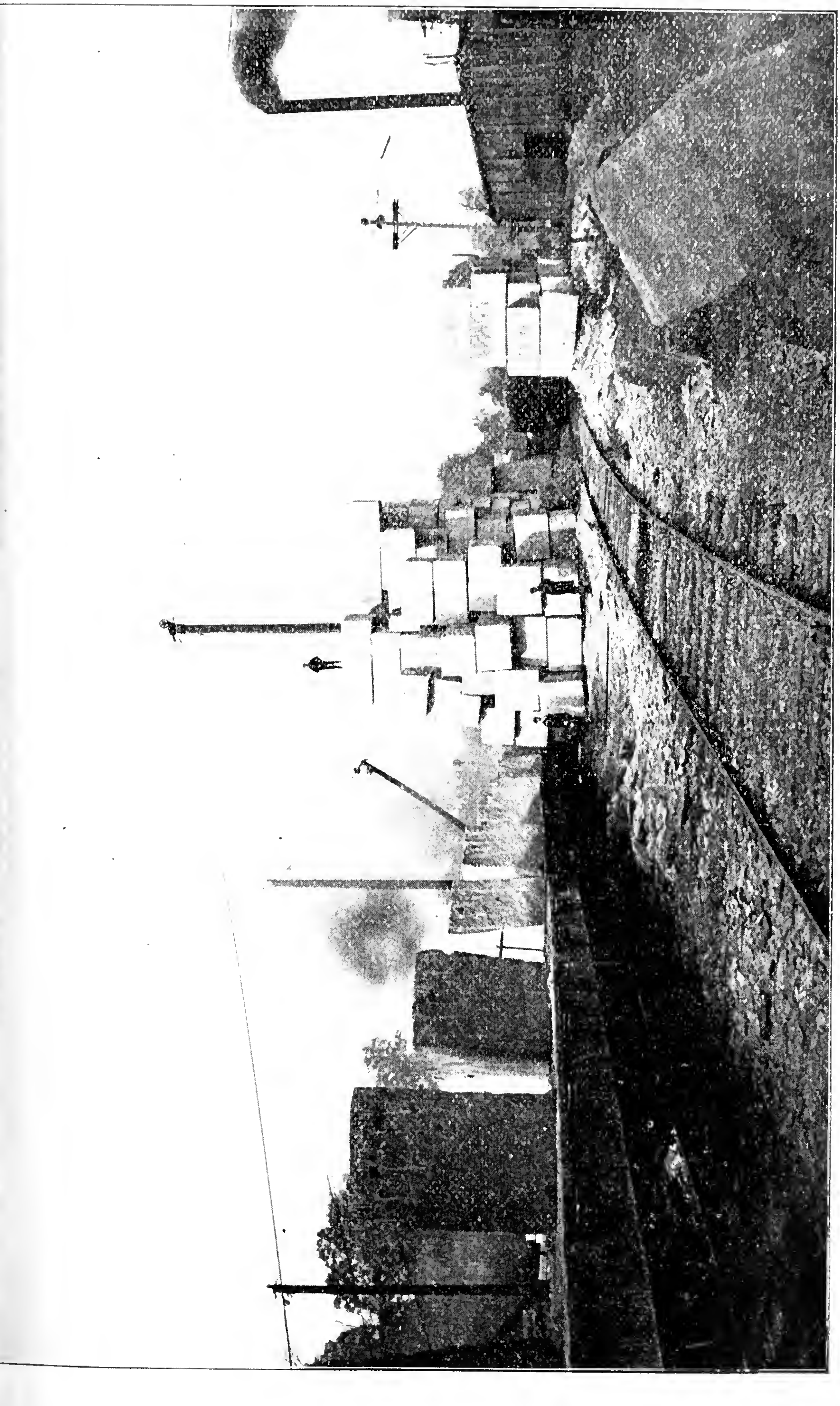


FIG. 133. BLUFF RIDGE QUARRY, NEAR BEDFORD, IND. CHARACTER OF STONE PRODUCED.

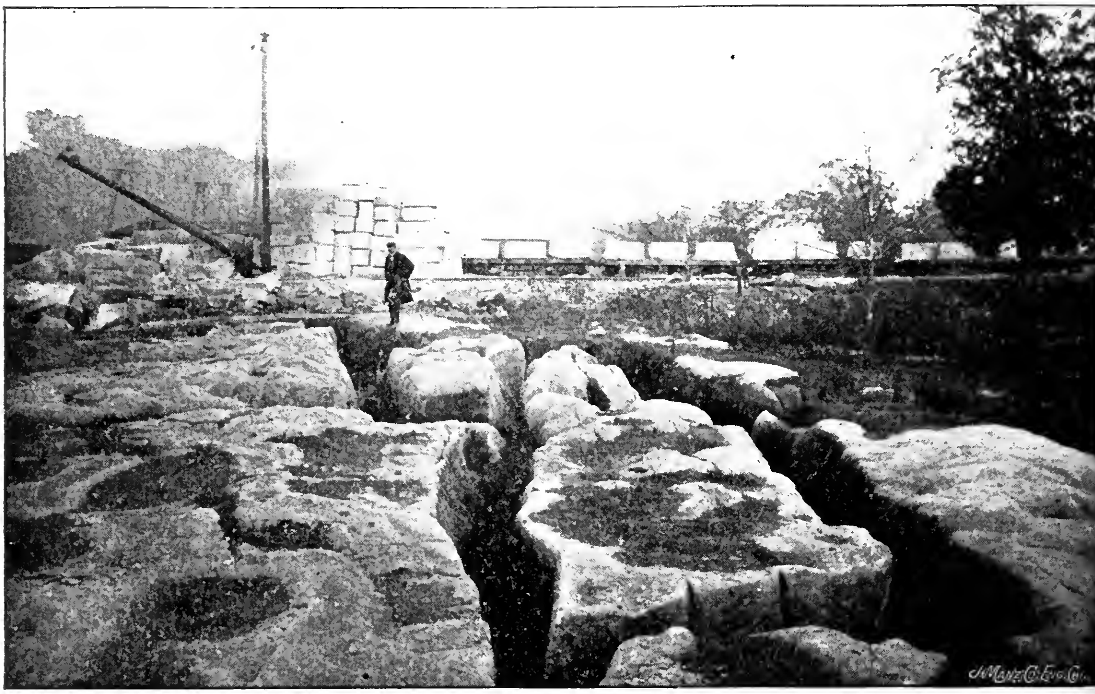


FIG. 134. BLUFF RIDGE QUARRY, NEAR BEDFORD, IND.
SURFACE OF ROCK AFTER STRIPPING.

qualities are not matters of conjecture, but are demonstrated every day.

In the construction of our new State house, we have used 4,000 car loads of this stone, and every day are more and more convinced of its great value as a building material.

We have had occasion to subject this stone to very severe tests, not only to its crushing strength, but tensile as well. We have lintels 18 feet long, with a clear span nearly 16 feet, with massive stonework built over these lintels. We know of no other stone that we would feel sure in subjecting to such a test.

JOHN M. GODOWN,
Secretary.

(b) BLOOMINGTON DISTRICT.

Bloomington was reached at an early hour, breakfast duly served at the Gentry House and a special train boarded at 8 a. m. The inspection began at the Hunter Valley Quarry, which was reached at 8:30 a. m. Fig. 121 is a view of this quarry which, as will be seen in comparison with following views, is of new development. There is shown in the center of the field a pile of stone as taken from the quarry, which may be either buff or blue in color, according to the depth from which it is taken, the blue being the beneath the buff.

Fig. 135. P. M. & B. Quarry, Near Bedford, Ind. View at Left and Center.

Walking across the hills by an easy path, and in as pure and exhilarating an atmosphere as a perfect autumn morning can produce, and in view of as bright and brilliant foliage as ever embellished an Indian summer day, the Star Quarry was reached at a distance of about one-fourth of a mile. Fig. 122 is a view taken at the west end of the quarry, where the pit is about 40 feet deep. Two large slabs of stone appear in the center of the field of view. The workmen are breaking up the near slab by the use of plugs and feathers. The farther slab is being drilled for the reception of plugs and feathers. Both slabs have been rolled over 90 degrees from their natural positions to facilitate working. The manner of removing the stones is the same at all quarries. Slabs of greater or less dimensions are cut from place by vertical cuts made by channelling machines. A series of holes are drilled horizontally on the bed in which wedges are afterward inserted. Driving the wedges splits the slab from its bed. It is then rolled over 90 degrees by use of levers and lines operated by the derrick power, or by other expedients. The slabs are then reduced to sizes that can be handled by the derricks or that are suitable for finished stones of particular sizes. Fig. 123 is a view of the quarry from its east end. At the right is seen the uneven nature of the surface of the rock and the extent of stripping. At the center a channelling machine is seen at work. At the left is a characteristic quarry derrick. In the foreground at the left is exposed a small area of the surface of the rock. A distinctive feature of the Star Quarry is the large size of stone blocks produced, many of which produce a plain face 10 feet by 15 feet, and having a sufficient thickness to make the weight 35 tons.

A train of flat cars was boarded and a novel and entertaining ride brought the party to the Chicago and Bloomington quarries at 9:45, in whose possession is 325 acres of stone land. These quarries are owned principally by Chicago people, who operate under the title of "Chicago Mill Owners' Co."

It may be noted that the nature of the stone at the several quarries varies, but its uniform sound quality is fairly indicated by the several views presented.

The mills of the Consolidated Stone Company were reached at 10:15. These mills are large and are perhaps as well equipped as any in the stone region. The equipment of saws, planers and headers is characteristic. Fig. 124 is a view of the machine shed and adjacent yards, including railroad tracks, traveling crane, blocks of stone, etc. At each of the doors of the shed is a machine, those nearest being saws, next to which are a number of planers and finally heading machines. Fig. 125 is a view of a set of saws. The stone in view has been divided into twelve parts by the saws, which are still in the saw-cuts. Fig. 126 is a view of a planer, upon which is set two stones, each being worked by the tools shown. Fig. 127 is a view of a header. The block of stone which is set in the machine has been planed on one side and the planing (heading) of the end of the block is being accomplished. The tool shown in the view works back and

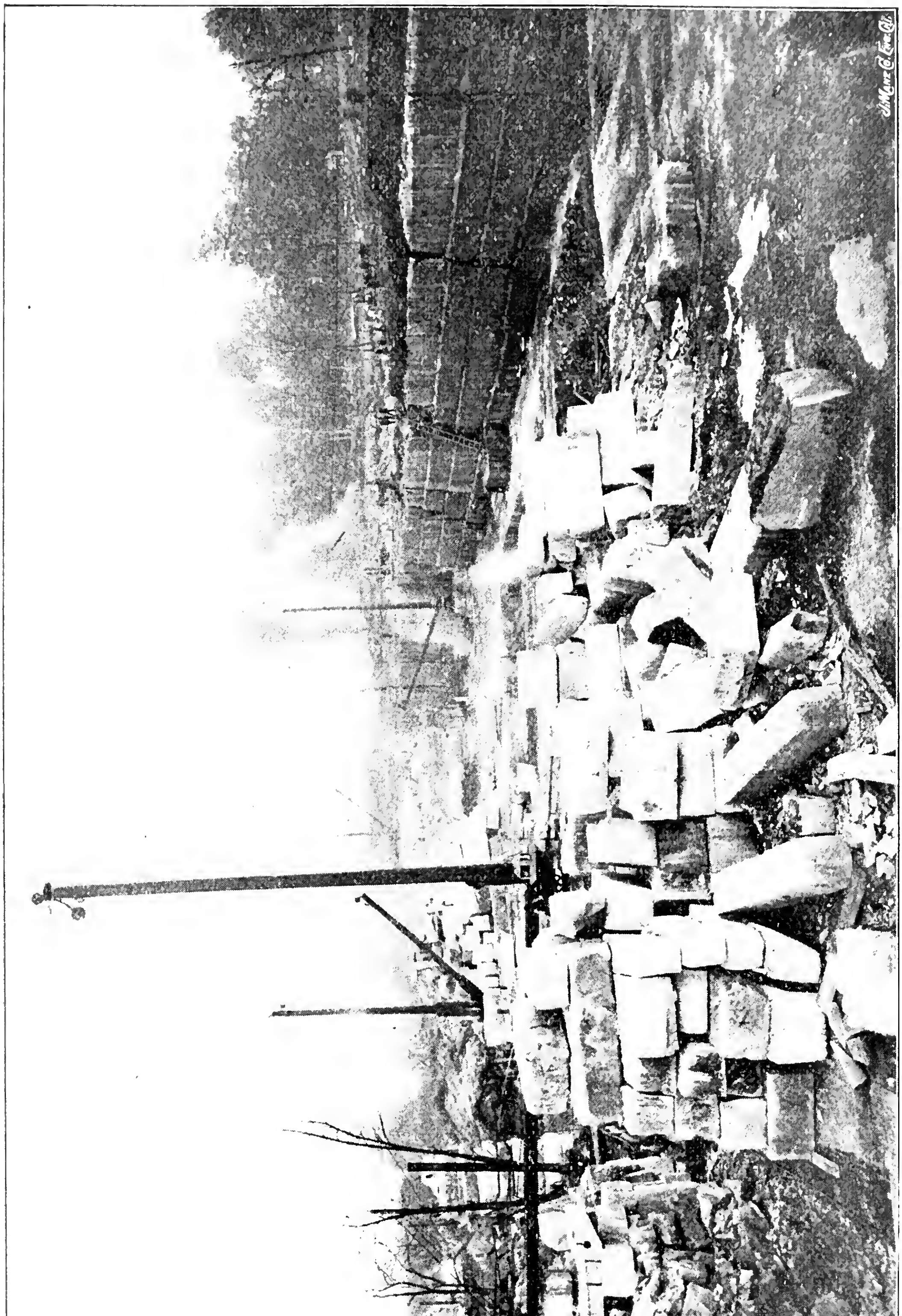


Fig. 136. P. M. & B. Quarry. Near Bedford, Ind. View at Center and Right

forth across the head or end of the block. The machine is virtually a planer cutting in a vertical instead of a horizontal plane, thus enabling the finishing of the end of a long stone. Fig. 128 is a view of a train of flat cars loaded with characteristic mill blocks ready to be delivered to the machines. Incidentally there is shown a partial view of the first quarry opened in the Bloomington District, known originally as the Hunter Quarry, but now owned by the Consolidated Stone Company. Fig. 129 is a view of the stone yard for hand cutting and is located just beyond the end of the machine sheds shown in Fig. 124.

Leaving the mill of the Consolidated Stone Company, the return was made to Bloomington in the special train of coaches. A stop was made long enough to attach a baggage car, the interior of which was fitted with a long lunch table laden with sundry edibles, which the morning's exercise, together with the cook's skill rendered decidedly palatable.

The Sanders' Quarry was reached at 12 m., lunch being served meantime. This quarry is located immediately on the line of the Monon Railroad, just south of Bloomington. They are quite extensive and of the same general nature as the quarries shown in the several views presented.

(c) BEDFORD DISTRICT.

A run of nearly thirty miles, affording a pleasant ride and a grateful rest after lunch, brought the party to the vicinity of Bedford. The party alighted at the site of the Salem-Bedford Stone Company Mill, a general view of which is shown in Fig. 130. Fig. 131 is a view of the yard adjacent to the mill, showing the traveling crane, and incidentally the party. The element of particular interest at this mill was the turning lathes, in which stone columns, balustrades, etc., are manufactured very much the same way as wood and iron is fashioned into shapes having circular cross-sections. A machine in which a column was being turned is shown in Fig. 132. At the rear of this machine are a number of machines in which smaller pieces were being turned. This mill is also equipped with planers and headers of the same description seen at Bloomington.

A special train on the Bedford Belt Railroad was boarded at the mill and the visit to the workings of the Bedford Quarries Company undertaken. The Buff Ridge Quarry was reached at 1:45 p. m. Fig. 133 is a view showing the character of stone taken from this quarry, all of which is of a buff color. Other quarries belonging to the company produce stone of a blue color. Fig. 134 is a very showing the uneven nature of the surface rock at this quarry when the overlying earth has been removed. The surface of the rock as shown in this view is not entirely characteristic of the surfaces generally developed in a number of these quarries. The deep corruga-

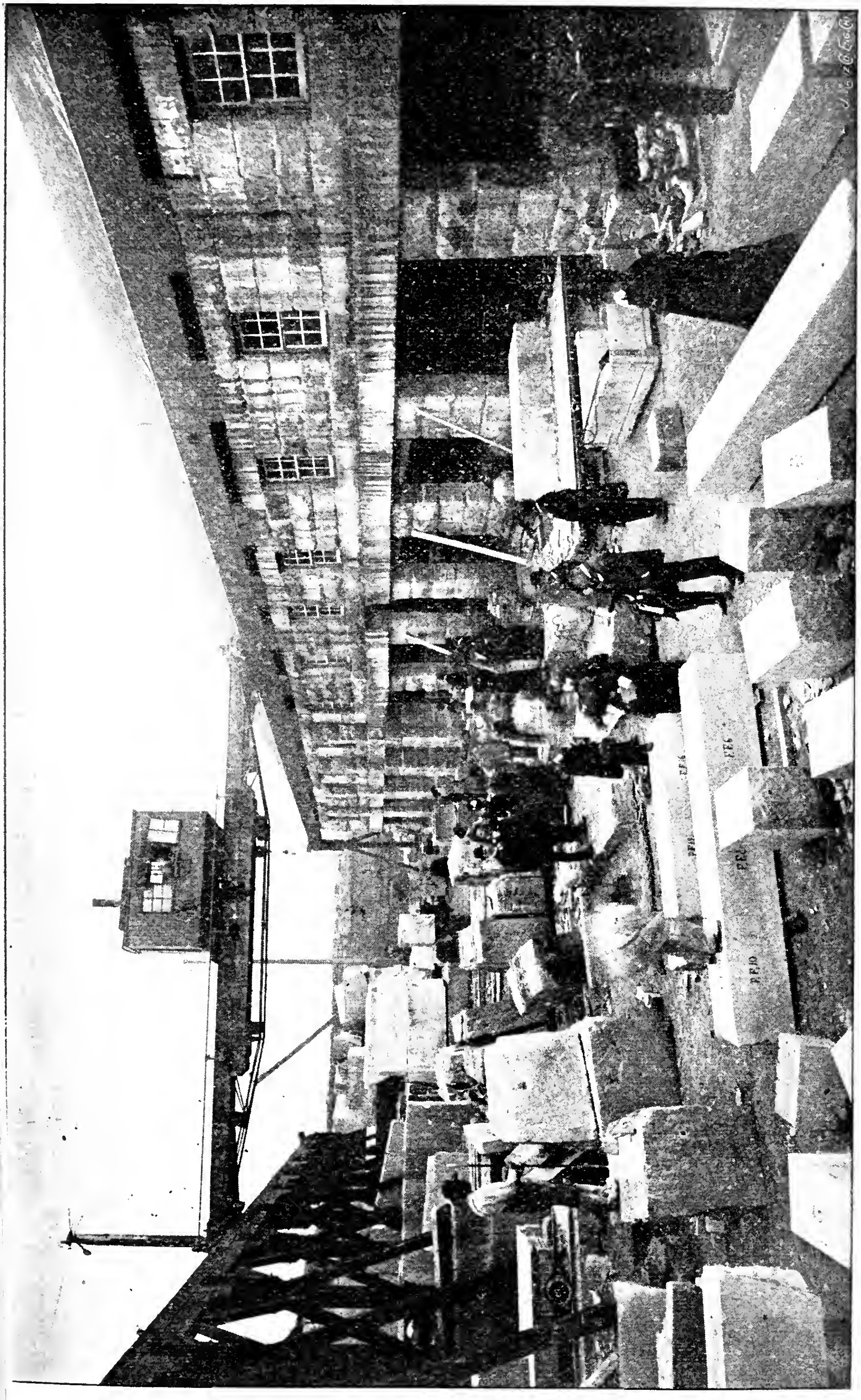


Fig. 137. Hoosier Quarry, Near Bedford, Ind. The Mill.

tions are indicative of what are called dirt seams, an instance of which will be illustrated further on. These seams will sometimes extend through the whole depth of a quarry and are objectionable on account of the large amount of waste stone a quarry will produce. Where they occur they are found to lie in an east and west direction.

A short walk brought the party to the P. M. & B. quarry, which has been very extensively worked. Its stone has been marketed in New York and other places quite remote, for use in public and other buildings. Figs. 135 and 136 are views of this quarry, the former being the left and center and the latter the center and right from the point of view.

The Hoosier quarry was reached at 2:45 p. m., and is another extensively worked and famous quarry. Fig. 137 is a view of the mill at this quarry, being a substantial stone building. It has an equipment of saws, planers and headers as at other mills illustrated. The view shows the traveling crane and characteristic blocks of stone. The mill at this quarry is said to be the largest of the Bedford District. Fig. 138 is a view at these quarries. At the bottom of the quarry is shown a slab of stone eleven feet high which has just been rolled from its natural place. It has been broken in three places in falling over and the breaks are in the line of nearly vertical dirt seams shown in the view near the ladder to the left. These seams were referred to in connection with Fig. 134. It is easy to see how they are a source of waste.

The day's inspection was finished by visiting the Indiana and Dark Hollow quarries, both extensive and well known, the character of which is well illustrated by the views already presented. Return was made to the starting point, where the party found the sleepers in waiting. Before taking departure, however, advantage was taken of the opportunity to thank our several hosts at the quarries.

In the absence of Mr. Wallace, president of the society, Mr. Johnston mounted a flat car and in the name of the Western Society of Engineers and all present thanked the stone companies for their kind hospitality and the royal manner in which the party had been treated.

Capt. Robert W. Hunt, ex-president of the society, was then called upon for a short speech. He could but express his surprise at the wonderful development which had been seen that day, and knew that the people of the quarries were preparing themselves for the prosperity which was near at hand, and that the "star of empire" would be arrested in its course to the great West and stay within our midst. That the time would come when not one railroad or two railroads, but any number of railroads would be required to bear their products to the great marts of the world, and that the time would come when there would be no North, no South, no East, or no West, as you have certainly proven to us to-day.

Capt. Wheat of the stone companies was then called upon and said that they were more greatly indebted to us for coming to see them than we were to them for any courtesies shown by them.

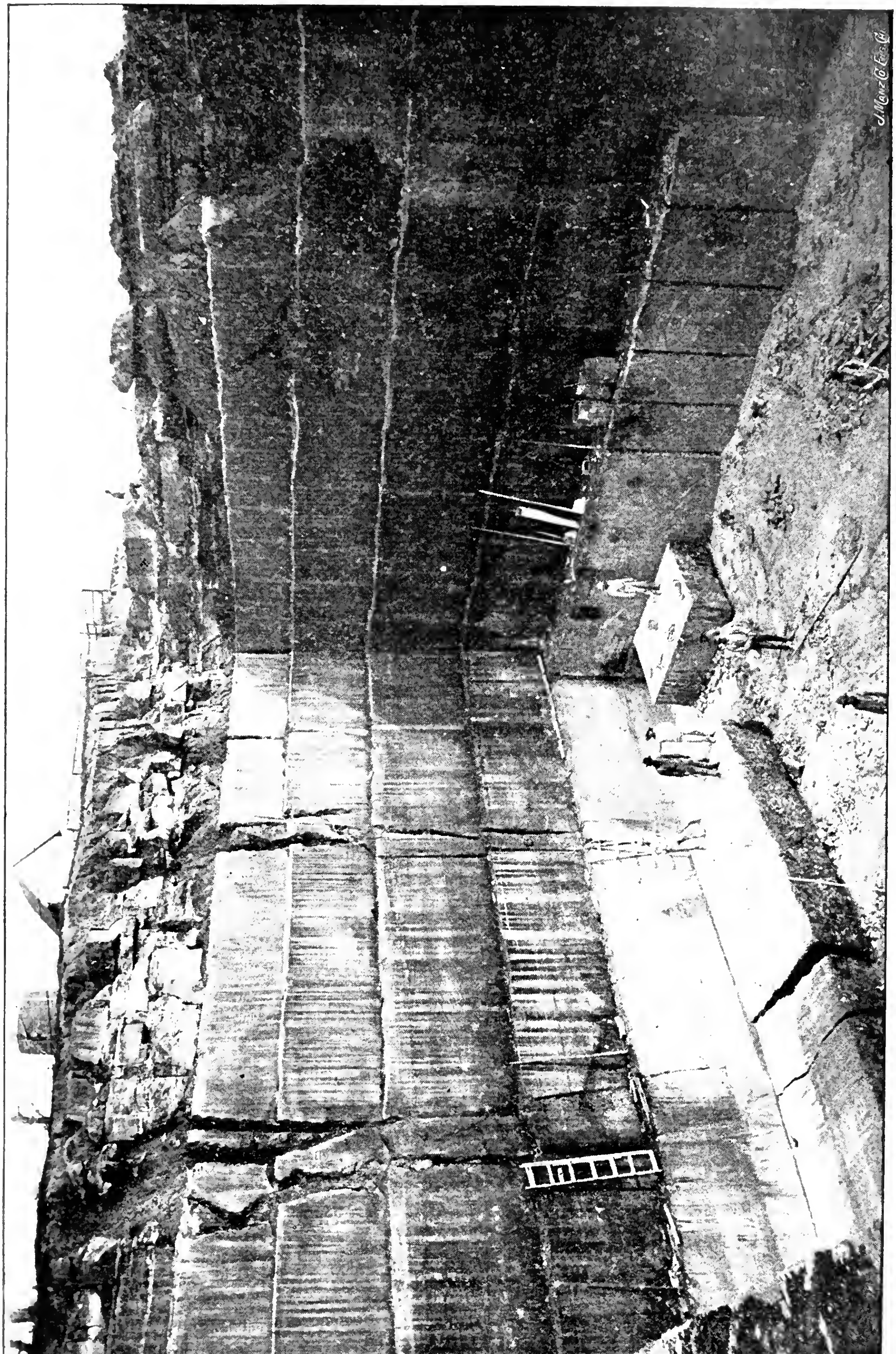


FIG. 138. HOOSIER QUARRY, NEAR BEDFORD, IND. SHOWING DIRT SEAMS.

"Many people had come to see them in the past, but never in all the history of the companies had any such a delegation been seen as we see here to-day. We are glad to see you and we are glad you appreciate this wonderful Bedford stone, and we hope you will impress upon all engineers that here is the best stone to be found in all Christendom. When any of you need any stone we hope that you will come to Bedford for it, as we can furnish it ad infinitum."

Leaving Bedford at 5:30 p. m., Louisville was reached at eight o'clock, where an elaborate dinner was served in the depot dining-room by the stone companies, much to the comfort of the party.

II. LOUISVILLE.

After a night of rest in the sleeping cars the party found a train of electric cars in waiting at the depot, which being boarded, departed for the Louisville Hotel, which was reached, after a pleasant ride in the frosty morning, in time for eight o'clock breakfast. The fact must not be omitted that on the preceding evening the party was welcomed to Louisville by Mr. T. A. Courtenay, Capt. Horton, Mr. Zollinger, Mr. Shaw and others, representing the Western Cement Company, whose guests the party became, and the Society of Engineers and Architects of Louisville.

Breakfast over, a special train provided by the Pennsylvania R. R. was occupied at the Main street depot, which, leaving at 9 a. m., crossed the Ohio river to Indiana and thence to the Falls City Cement Mill, about ten miles distant from Louisville. Here the inspection of the manufacture of Louisville cement began.

(a) LOUISVILLE CEMENT.

It will be useful, before presenting the illustrations reproduced from Mr. Grant's photographs, to note the general nature of the cement industry. A ledge of rock crosses and forms the bed of the Ohio river at Louisville. It is the cause of a rapid fall in the river through a distance of several miles, which in turn caused the construction of a canal for navigation, extending from above to below the falls. It is an interesting fact that the development of most of the cement industries of the United States is closely linked with the construction of canals where the cement-making materials are found, and the case of the Louisville cement is no exception to the rule. Outcropping in the bed of the river on the falls is a rock so constituted that a hydraulic cement can be made from it, and it is there that the Louisville cement industry originated more than half a century ago. This rock, though extending southerly into Kentucky, beneath the city has not been explored in that direction. It extends northward into Indiana and is found near the surface over an area of many square miles. Including those on the river falls with those in Indiana, there are now thirteen localities at which cement is made, the combined capacity of the mills being about 2,000,000 barrels per annum. The mills are located generally on the line of the Pennsylvania and Baltimore and Ohio Southwestern railroads. The raw material is so abundant that many more mills can be established when occasion requires. The rock having been quarried and reduced to suitable size for handling, it is placed in a kiln together with a suitable quantity of coal, the result of burning, which is done at a low temperature, being to drive out the combined water and carbonic acid, the rock being reduced to an anhydrous state. The burned rock is then

reduced to a fine powder by passing it through crushers, grinders and burr stones. The result is an hydraulic cement.

The Falls City Mills have been existence many years. The rock was originally taken from an open quarry, but for several years past has been mined. Fig. 139 is a view of the entrance to the mines, the floors and roofs of which are not rock suitable for making cement. The thickness of the cement rock is therefore shown by the height of the entrances. The mines extend several hundred feet from the entrances and are frequently interconnected by numerous passages. They are sufficient in size to admit small locomotives which haul cars loaded with rock from the mines to the kilns. The distance from floor to roof is between twelve and fifteen feet, and from wall to wall generally between forty and fifty feet. At one locality an unsupported roof span of ninety-six feet was stepped off.

Entering the mines, they were found to be conveniently dry for walking and well lighted by incandescent electric lights. Red and green fire intermittently burned at odd nooks in the mines produced a pyrotechnic effect at once beautiful and impressive. Reaching the extremities of the mines men were found drilling holes to receive the explosives for blasting the rock, the drills being worked on vertical bars fastened at roof and floor. Fig. 140 is a view at the end of a mine immediately after firing a blast. The step ladder affords a basis for estimating dimensions.

Leaving the mines, the kilns, to which the rock is taken, were visited. A general view of these is shown by Fig. 141. They are continuous in their action. The coal and stone, mixed together, are dumped in the top and the calcined product withdrawn from the bottom and loaded into cars which convey it to the upper floor of the mill. There it is first crushed to about the size of an egg or smaller. It is then passed through conical iron grinders which reduce it to a sand, which is then fed through burr stones. It is not ready for packing in barrels or sacks, however, until sifted. This is accomplished by being passed over a wire screen having meshes about one-eighth of an inch square made of No. 16 wire. The screens are set at a suitable angle with the vertical. The material from the burr stones is fed on the screen at its top and allowed to descend by gravity. Momentum insures the passage of the coarser particles over the screen without passing through it, finally reaching the bottom of the screen, from which they are conveyed back to the burr stones for finer grinding. The particles sufficiently fine for cement fall through the screen and are conveyed to the packing room where they are received in barrels or sacks. The capacity of this mill per day is about 2,500 barrels of 265 pounds net.

Fig. 142 is a general view of a mill to the east of the Falls City Mill.

The Speed Mill, three miles distant, was next visited. Passing by the mill for the time being, the party was taken at once to the

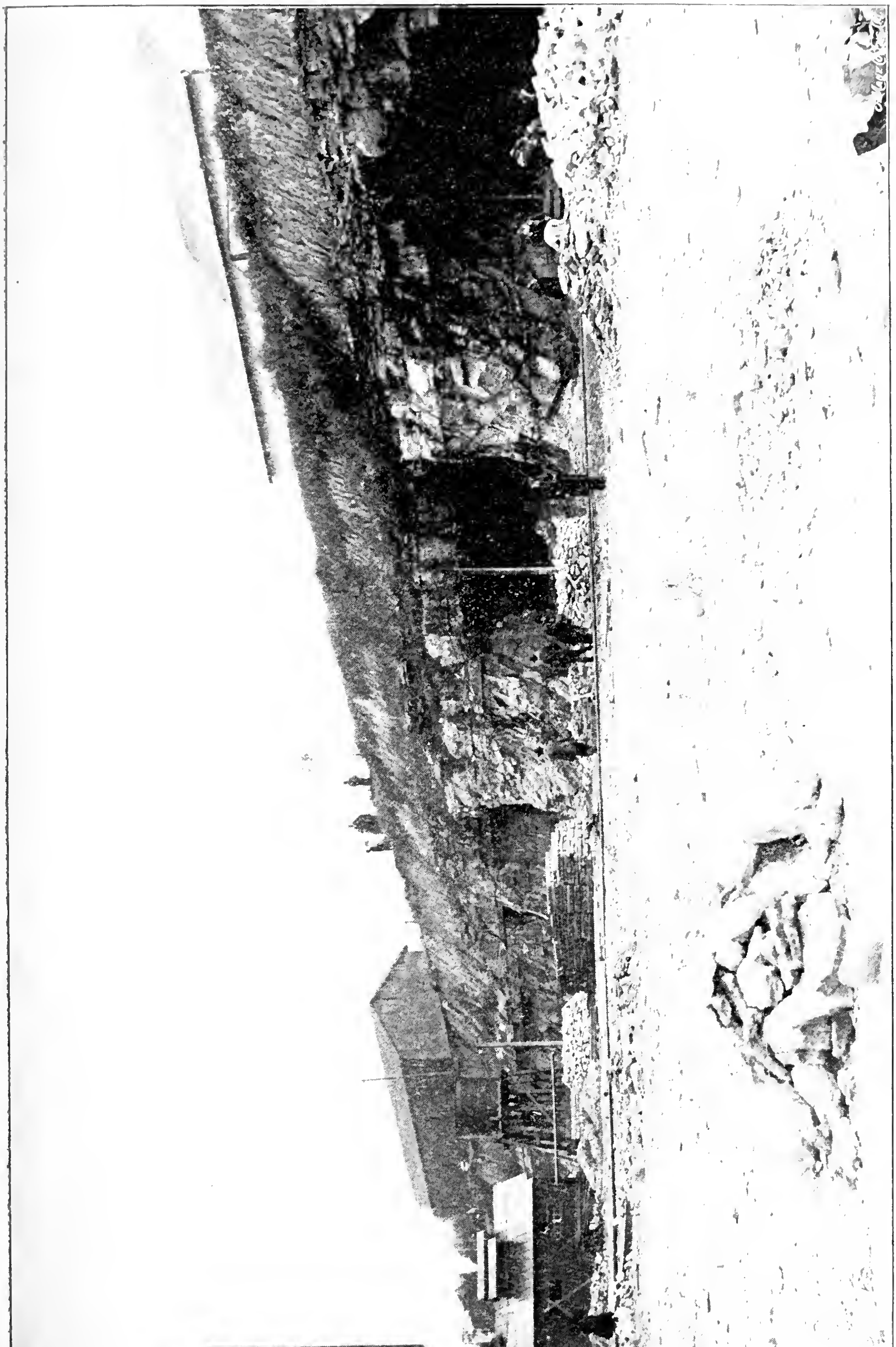


FIG. 139. LOUISVILLE CEMENT WORKS. ENTRANCE TO MINES AT FALLS CITY MILLS.

quarry, distant about one and one-half miles from the mill. This was reached over a well constructed narrow gauge railroad. The trip was made in a number of the interesting cars in which rock is hauled from the quarry, seats being arranged in them for additional comfort. Fig. 143 is a view of the quarry face and illustrates the physical nature of the rock fairly well. The thickness of the rock deposit is shown and the small amount of stripping. There is a very thin layer of overlying rock that must be included in the stripping.

Fig. 144 is a view of the quarry face just after a blast. The method of working the quarry, which is exceedingly meritorious, is also shown. The several skips into which the workmen are loading rock are nothing more nor less than car bodies. Being flat and open at one side the rock is placed in them with a minimum of labor. A train of empty cars being run into the quarry on the track most remote from the face, the empty bodies or skips are lifted by the traveling derrick by the bales shown in the figure and swung to a suitable place at the face. A loaded skip is then lifted similarly and placed on the trucks from which the empty skip was removed. The process is repeated until a trainload of the rock is formed, which is then hauled to the mill. After witnessing a blast the party returned to the mill.

A general view of the kilns is shown in Fig. 145. The mill is at the right, just out of the field of view. In the background is seen the roof of the stone crusher. Surmounting the kilns is shown a large coal bin in the foreground and a hoisting engine shed at the center of the view.

Fig. 146 is a view of the crusher looking from the kilns. At the right is shown an inclined track to the upper floor, up which the rock-laden cars from the quarry are hauled ready for dumping into the throat of the crusher by means of a rocking floor which rotates the whole car. In passing through the crusher the rocks, broken into various sizes, are received upon huge screens made of iron bars, which have the effect of sorting the several sizes and delivering them, thus separated, into one or the other of the several cars shown beneath the shed.

Fig. 147 is a view of the tracks leading from the crusher to the top of the kilns. The cars are hauled over these by wire rope, all cars containing a particular size of rock being taken to a kiln in which that size is being burned. The object of this operation, which is not generally the practice at the several mills in the vicinity, is to secure a more uniform burning of the rock. The smallest sizes are about the size of an egg, the largest about as large as a man's head.

Fig. 148 is a view of the mill and the kilns adjacent thereto, which are to the right of the view shown in Fig. 145. As at the Falls City Mill, the kilns are continuous in their action. At the center of the view is seen the track leading from the bottom of the kilns to the upper floor of the mill, over which the burned rock is hauled, to

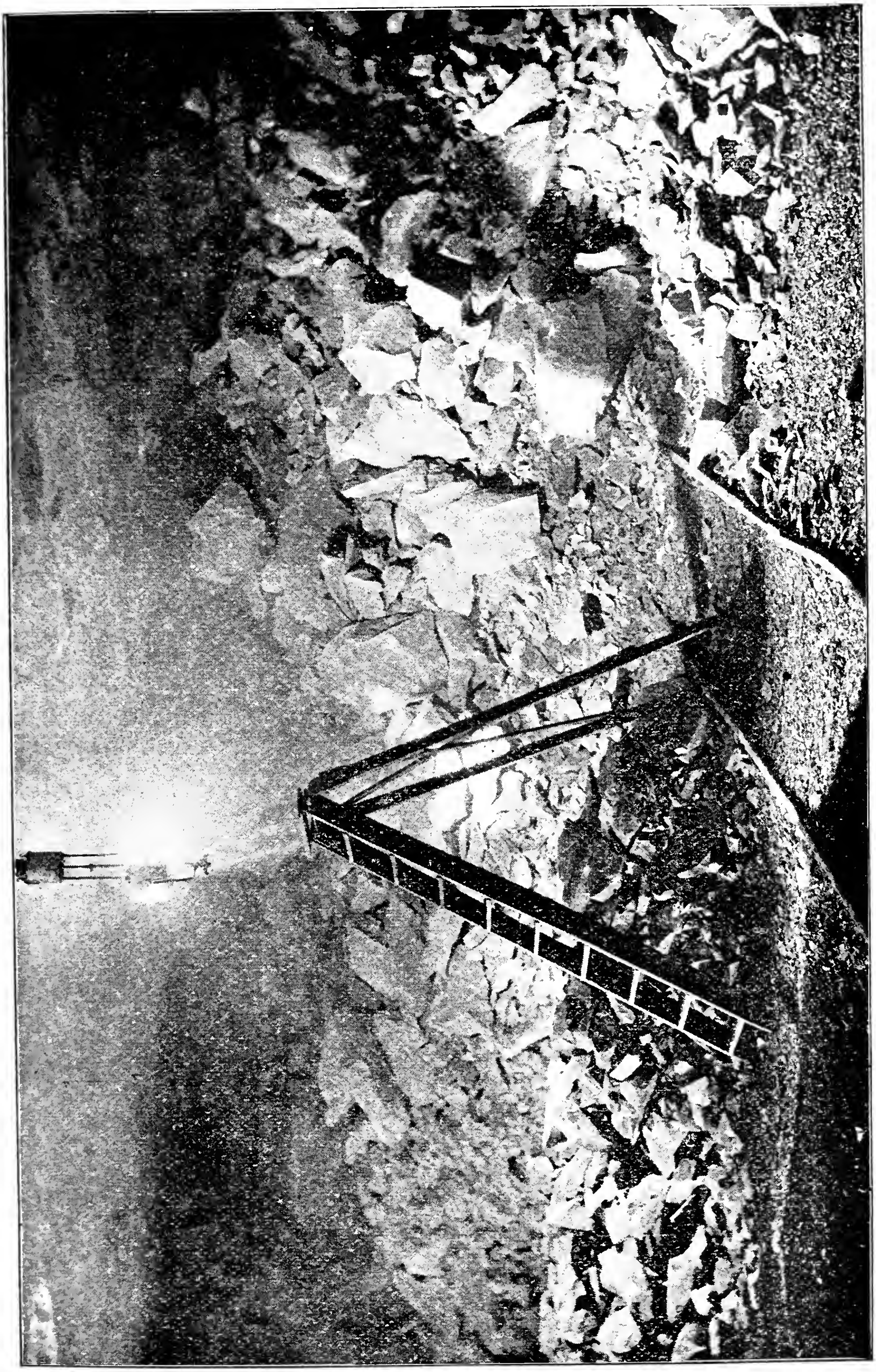


FIG. 140. LOUISVILLE CEMENT WORKS. VIEW AT END OF MINE AT FALLS CITY MILLS.

be afterwards treated in the same manner as previously described. The rated capacity of this mill is 3,000 barrels per day of 265 pounds net.

Noontime having arrived the party proceeded to their train and found tables arranged in the cars, laden with a luncheon of rare and delightful quality. The way to it was paved with that exhilarating Kentucky product which cements friendships and dispels care. The way from it was equally inviting, as was demonstrated by the abundant provision of the best of French vintage.

(c) THE BRIDGE.

The departure from the cement mills, where the visit had been so pleasant and entertaining, was made at about 2 p. m. A short ride, and the junction with the Big Four R. R. was reached, and transfer made to a special train tendered by that road. Another short ride and the train stood on the new Merchants' bridge, over which that road crosses the river. Here, as guests of Mr. Selby, engineer of the bridge, the gentlemen of the party made an inspection of the 550 feet span. This being done, another short ride, and the party was delivered on board the steamboat City of Jeffersonville preparatory to a river ride of about three miles to the water works.

(d) THE WATER WORKS.

Scattered about the boat the party enjoyed the view of the city and surrounding hills, and found opportunity for social converse and merriment. Reaching the works the banks of the river were mounted to the level of the pump rooms. The magnificent pumping engine was a source of great interest to everyone, as was the boiler room, the great stone stack, the standpipe, and other details of the plant.

After examining the works very carefully, Mr. Johnston, first vice-president of the society, introduced Mr. Charles Hermany, the superintendent and engineer of the water works, who in the name of the city of Louisville, in the name of the Louisville Water Co., and in the name of the Engineers & Architects Club of the city of Louisville, bid the party welcome. He said: "We feel honored, ladies and gentlemen, to have your visit to-day, and we hope that your visit has been both pleasant and profitable. We also hope to know you better. Most of the people before me at this time are strangers to me and perhaps to the city of Louisville. I have been called upon unexpectedly to bid you welcome, but to make a speech is something entirely out of my line of business.

"I have been very greatly interested in making experiments with the water of the Ohio, hoping to be able to find a process which will make it both pure and clear as crystal. Experiments made in both England and Europe for filtering large bodies of water have been very costly. In this country no effort has been made to purify

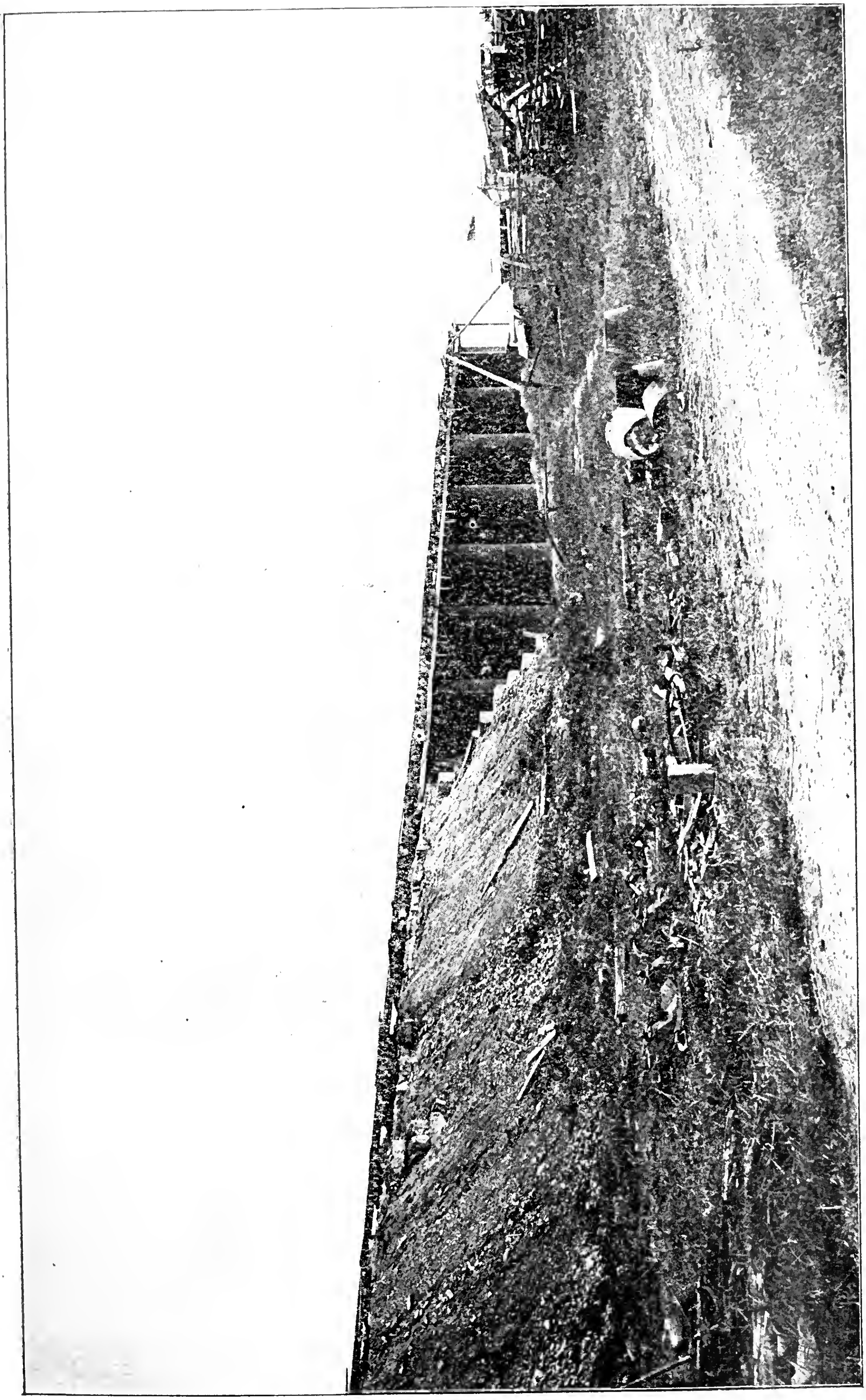


FIG. 141. LOUISVILLE CEMENT WORKS. KILNS AT FALLS CITY MILLS.

water upon a large scale that is known to be as difficult to treat as the water of the Ohio river, hence these experiments were prosecuted with a great deal of care and have been brought to a conclusion. The final report is now in the hands of Mr. Geo. W. Fuller of Boston, who has had charge of the work, and he has also had personal charge of conducting the experiments.

"I hope, gentlemen, that your visit to the cement works this day will impress you more than heretofore with the importance of work of that character and the scale of magnitude upon which the work is carried on, at and about Louisville, and the reputation of turning out a very superior hydraulic cement.

"It has given me pleasure to meet so many distinguished engineers, especially so many of the members of the Western Society of Engineers. I think such excursions are to be commended, as they cannot but be both profitable and interesting. The close relations between the many members of our profession should be encouraged; we should know each other better. I regret that there are so many of you with whom I have so little acquaintance; this being the first time I have had the pleasure of meeting so many of you, but I hope it will not be the last time.

"With reference to this pumping station you will permit me to say that it was opened in the fall of 1888. The structure in which we are assembled is built upon a pneumatic caisson. The entire foundation of the superstructure rests upon a pneumatic caisson 85½ feet square. There is no foundation here except sand. The bed rock underlies the foundations of the caisson about 65 feet, therefore it was deemed impossible and unnecessary to go to bed rock and the caisson was founded in sand. This is 24 feet below low water.

"The pumping engine which you see was built by the J. B. Morris Co. of Philadelphia. It is a compound engine and has a capacity of 16,000,000 gallons for 24 hours. It is pumping at this moment about 18,000,000 gallons and can be speeded up to pump 20,000,000 gallons every 24 hours. I make this statement in answer to questions addressed to me upon this subject by Engineer Randolph. I may be permitted to say that so far as I am informed this was the first large caisson that was attempted to be sunk as this was. It was deemed impossible by some on account of the breaking of the masonry, but it was done without any trouble and was in every way a success. One of the important features connected with the structure was that after it was sunk it was to be loaded with a machine weighing over 500 tons on one-half of it without any corresponding weight on the other half, and it gives me pleasure to state that not a particle of unequal settlement has taken place on account of loading one side and operating the pumping engine thereon. I make this statement for the benefit of those who may have similar problems to solve in the future.

"As I stated before, I did not come prepared to address you or to enlighten you upon engineering matters in general. If there are any questions any of you brother engineers desire to ask upon this

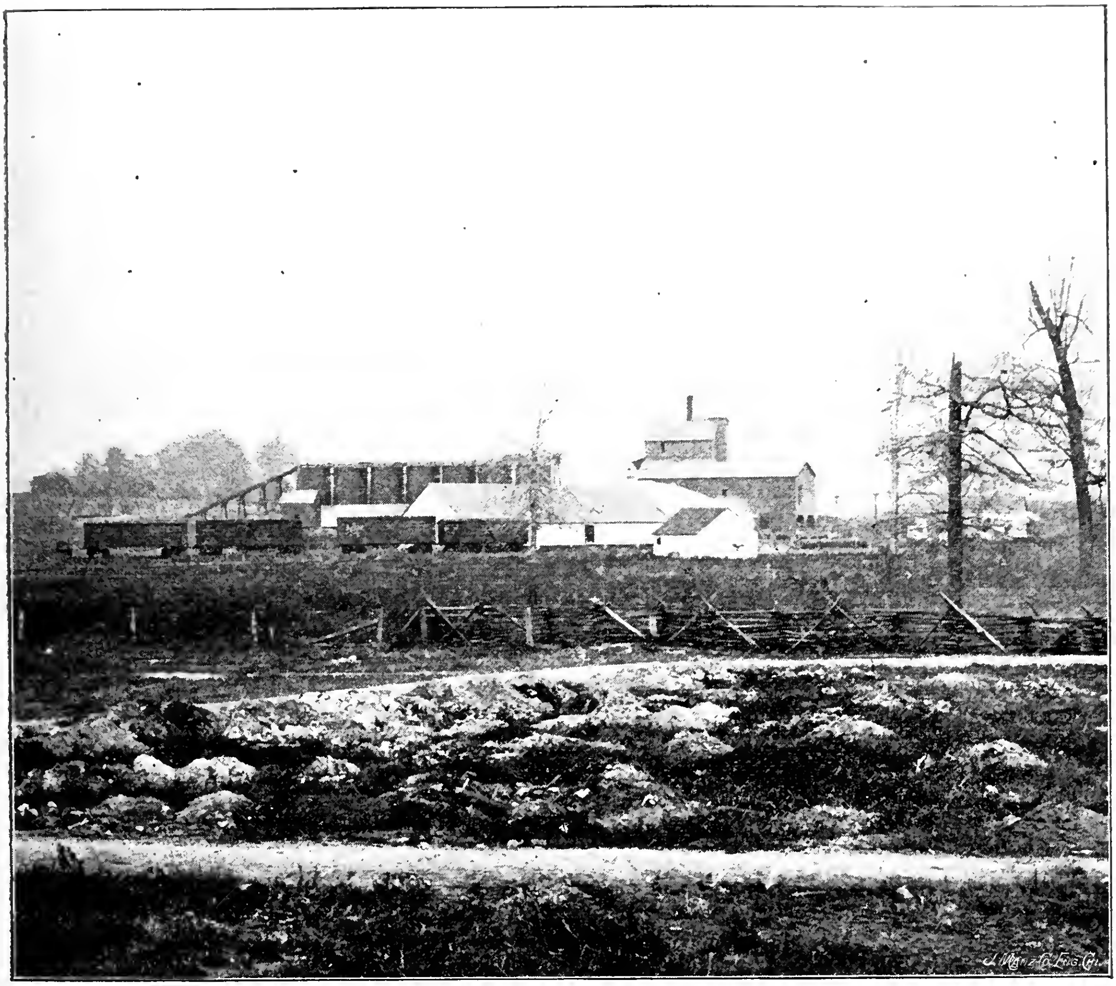


Fig. 142 Louisville Cement Works. General View of a Mill.

work it would give me pleasure to answer them; if not, I will ask you to adjourn to the house across the way to examine an experimental filter. We have experimented with four different kinds, the experiments terminating on the last day of July. All of the filters experimented with have been refused; the one remaining is being operated by the kindness of the O. H. Jewell Co. of Chicago. The water shown on the table gives the water as taken from the Ohio river before filtration and after it has been filtered, of which we ask you to take a drink. Again, in conclusion, permit me to thank you for this visit, which will ever be remembered by us."

The Louisville Hotel was again reached at 6:30, where dinner was served. After dinner the entire party adjourned to the parlors, where Mr. Johnston on the part of the Western Society of Engineers and everyone present, thanked the Louisville Cement Co., whose guests the party was, and all others who contributed to the entertainment for the courtesies extended. and that the party should consider itself indebted to them for all time to come.

Capt. Hunt was then called upon and said that he had no speech to make other than to thank the good people who had entertained so royally. "Yesterday our party visited the great quarries from which the stone is taken and to-day we have visited the works and seen the stone which is used to make the cement with which these great stones are held together; may it be a symbol to us of lasting friendships made cemented together by nearer intercourse with one another, and we ask one and all of you to come to see us when we hope to be able to treat you as well as we have been treated in Kentucky. Our worthy president could not be with us, but Mr. Randolph and myself, who are ex-presidents and claim the south as our birthplace, know how genuine is your hospitality. Again expressing to you my most sincere thanks, we shall have to part."

(b) THE CEMENT.

The cement is hydraulic, a characteristic analysis being as follows:

Water	1.16 per cent.
Silica and insoluble matter	21.10 " "
Alumina and oxide of iron	7.51 " "
Calcium oxide	30.16 " "
Calcium carbonate	25.42 " "
Magnesium oxide	7.00 " "
Sulphate of calcium	6.85 " "
Alkalies and loss	.80 " "
	100.00 per cent.

The statements herein made have reference to a good quality of cement, such as may easily be obtained under such inspection and tests as are now easy to be had.

It may be termed quick-setting. A number of examinations of rate of setting made by the Sanitary District of Chicago show it to be very uniform. It requires about 15 minutes for initial set and 40 minutes for final set. The former was determined at the time when a wire one-twelfth (1-12) of an inch in diameter, loaded to weigh one-fourth (¼) pound, ceased to make an impression in a pat made of 100 parts by weight of cement to 40 parts by weight of water. The latter was determined at the time when the same pat ceased to receive an impression from a wire one-twenty-fourth (1-24) of an inch in diameter loaded to weigh one pound. The rate of setting is far more uniform than many of the Portland cements made at one and the same mill. The run of cement from some of the Portland mills will at one time take initial set in one minute and at another time not until after several hours.

The fineness of the cement is also uniform, a great many observations showing it to be generally as follows: 80 per cent will pass a No. 100 sieve and 92 per cent will pass a No. 50 sieve.

The cement, as ordinarily shipped, weighs 265 pounds net to a barrel of 3.75 cubic feet, slightly more than 70 pounds per cubic

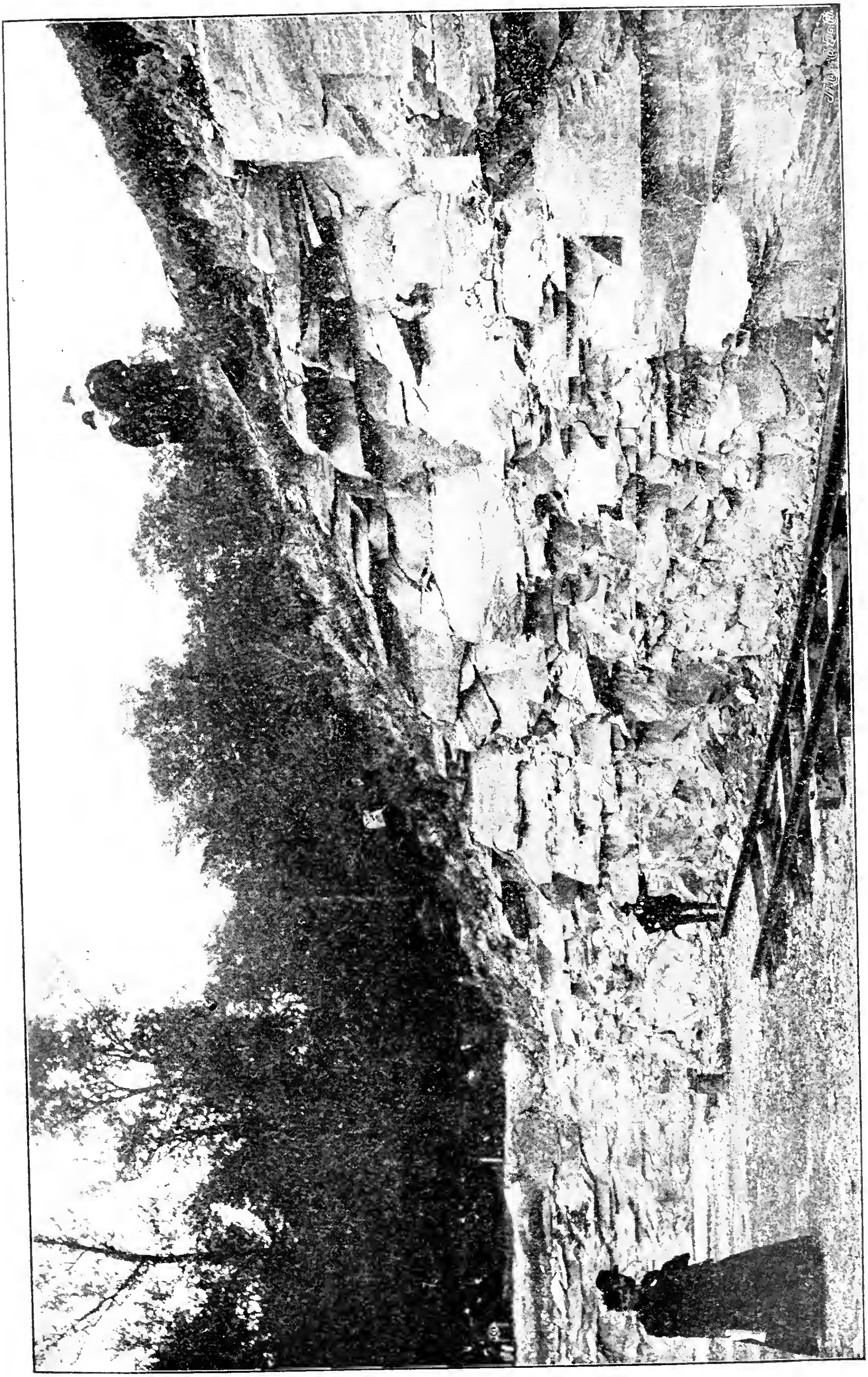


FIG. 143. LOUISVILLE CEMENT WORKS. FACE OF QUARRY AT SPEED MILLS.

foot. It is more generally shipped in jute or paper sacks, each containing half a barrel. When loosely compacted it will weigh as little as 50 pounds to the cubic foot. It has been found on the works of the Sanitary District of Chicago that the contractors use it in such a manner that a cubic foot will weigh about 65 pounds. In specifying the quantity of the cement that should be used in mortar a given weight of it should be required for each cubic foot of sand. When made into mortar without sand its weight per cubic foot when well set and dry is about 103 pounds per cubic foot; when made into mortar with sand in the proportion of 65 pounds of cement to one cubic foot of sand the weight per cubic foot is about 117 pounds.

The rate of hardening of the cement mortars is a quantity depending largely upon the conditions under which the mortars are made, especially the temperature. At temperatures not far from 70 degrees Fahrenheit the figures in the following table are characteristic:

	——Tensile Strength per Square Inch.——					
Kind of mortar—	1 day.	7 days.	28 days.	3 mos.	6 mos.	1 yr.
Neat	100	150	200	250	330	400
1 to 1		100	150	220	260	280
2 to 1		60	90	150	180	200

The neat mortar is made of 100 parts cement to 36 parts of water by weight. The 1 to 1 mortar has 100 parts of cement, 185 parts of sand and 43 of water, all by weight. The 2 to 1 is of 100 parts of cement, 370 parts of sand and 55 parts of water by weight. The sand is what is known in Chicago as coarse beach sand. All briquettes more than one day old were kept in air under a damp cloth for 24 hours and then immersed in water. Briquettes for breaks one day old were put in water as soon as they could be taken from the molds. The table is based on a numerous series of tests made by the Sanitary District of Chicago.

The influence of temperature on the rate of hardening is well illustrated by a case occurring in the Sanitary District testing rooms. Thirty briquettes taken from a carload (165 barrels) in August, 1896, when the weather was and had for some time been excessively warm, developed an average tensile strength of 230 pounds per square inch in seven days. Another set of thirty briquettes taken from the same packages some time later when the weather was much cooler developed an average strength of 145 pounds in seven days. Furthermore, a number of carloads of cement received during the warm weather developed unusual high strength. There need be no trouble in obtaining cements which will at all times, when testing-room temperature is above 40 degrees Fahr., develop a strength greater than 100 pounds per square inch in seven (7) days.

The degree to which the cement rock is burned will affect the rate of hardening. If underburned it will harden rapidly and develop high strength in seven days, and herein is a danger in dependinig solely on seven day tests to finally determine the merits of the

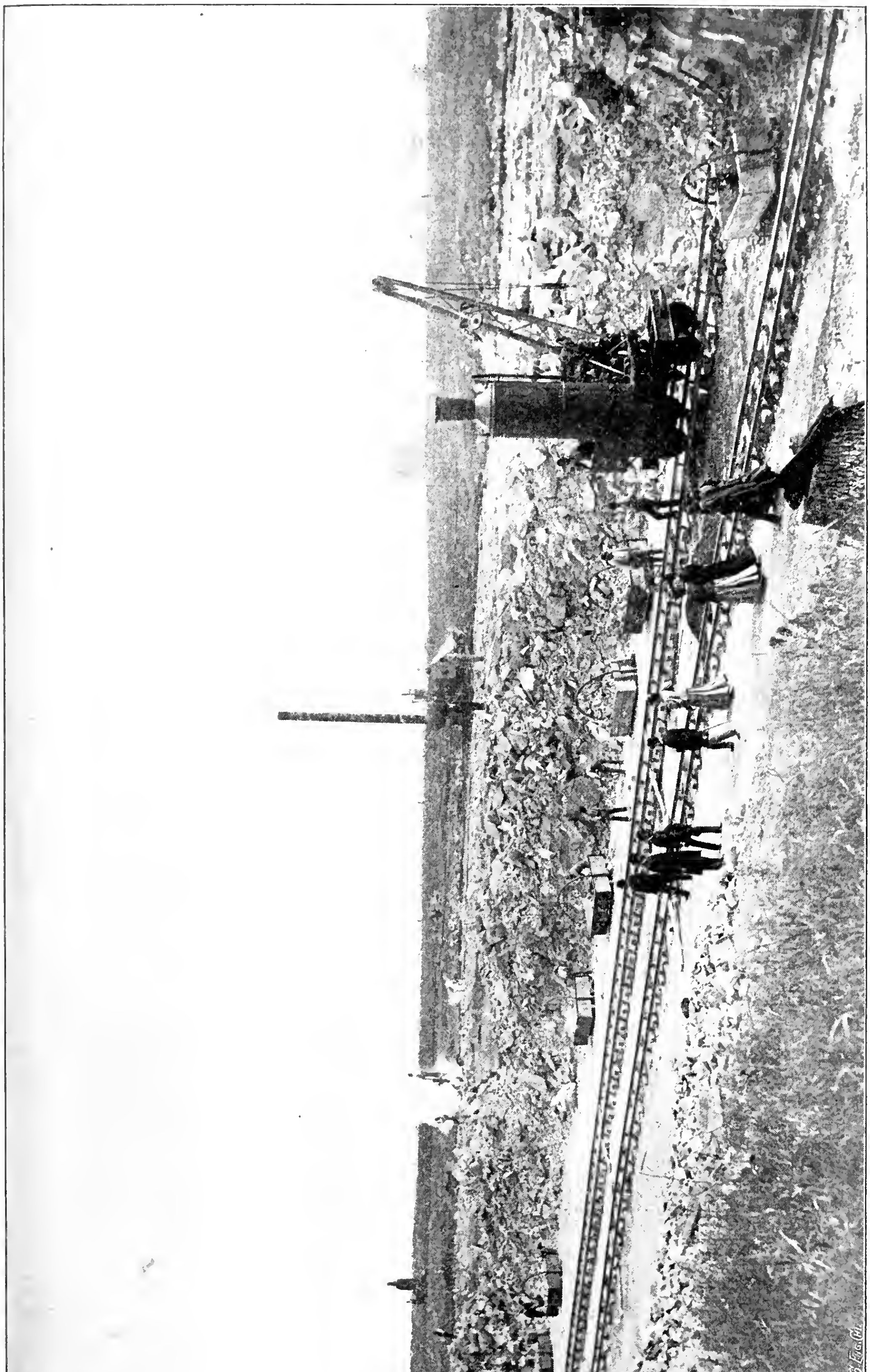


Fig. 144. Louisville Cement Works. Method of Quarrying at Speed Mills.

cement. Those familiar with the cement can detect it by its color or in other ways. Inspection of the cement at the mills is a safeguard. If underburned too much the strength may diminish as time goes on. If overburned the strength will develop slowly and be low in seven days and perhaps never attain the characteristic magnitude belonging to good cement. Insofar as care in manufacturing is concerned, defects due to under or overburning are much less liable to occur in the manufacture of Louisville than in the making of Portland cement, and are more easily detected.

The influence of temperatures below the freezing point upon the hardening of mortar is important. When the mortar has been allowed to harden for a week before being subjected to freezing conditions it will, if well made in proper proportions of cement and sand, resist disintegration, though large blocks may crack on account of contraction, just as Portland cement mortar blocks will do. The mortar having set, the mere fact of having its temperature reduced to the lowest occurring in this country will not affect it. If it be allowed to become saturated with water before freezing, then disintegrating tendencies are set up by the expansion of the water on freezing. If the cohesion of the cement and its adhesion to sand be sufficiently strong disintegration will not take place. On this account Portland cements are better. Furthermore, it is not practicable, in ordinary work, to make a mortar that will not be porous, and it is certain that air in the pores will defeat thorough saturation unless under very exceptional conditions. The result is that as the contained water expands in freezing the particles of cement are free to move and if the elastic limit of the cement be high enough the tendency to disintegration will be counteracted. Be the theories what they may, experience shows that a one to one or two to one Louisville cement mortar has sufficient resistance to defeat disintegration in this climate, if well made, even if the block be dried out and be well wetted occasionally when exposed throughout a winter. If the mortar be made in freezing weather the dangers are greater. The water in the mortar may freeze before hardening proceeds sufficiently far and there will therefore be no water to complete the hardening. The ice may evaporate before thawing and the cement be left dry when warm weather comes, and thus be prevented from hardening. A concrete dam constructed near Chicago was partly builded during freezing weather and remained exposed throughout a whole winter. The following spring several inches of the surface of the concrete peeled off, but the interior hardened. The hardening proceeded quite slowly, as was determined by occasional examinations during the winter, but nevertheless hardened. That part of the concrete which peeled off failed for two reasons. First, it lost its water before hardening was perfected. This fact prevented it from attaining enough strength to resist the expansion of water in it on freezing. The interior retained its water, however, and eventually hardened.

The effect of tempering Louisville cement mortar is interesting. A number of experiments made by the Sanitary District show that,

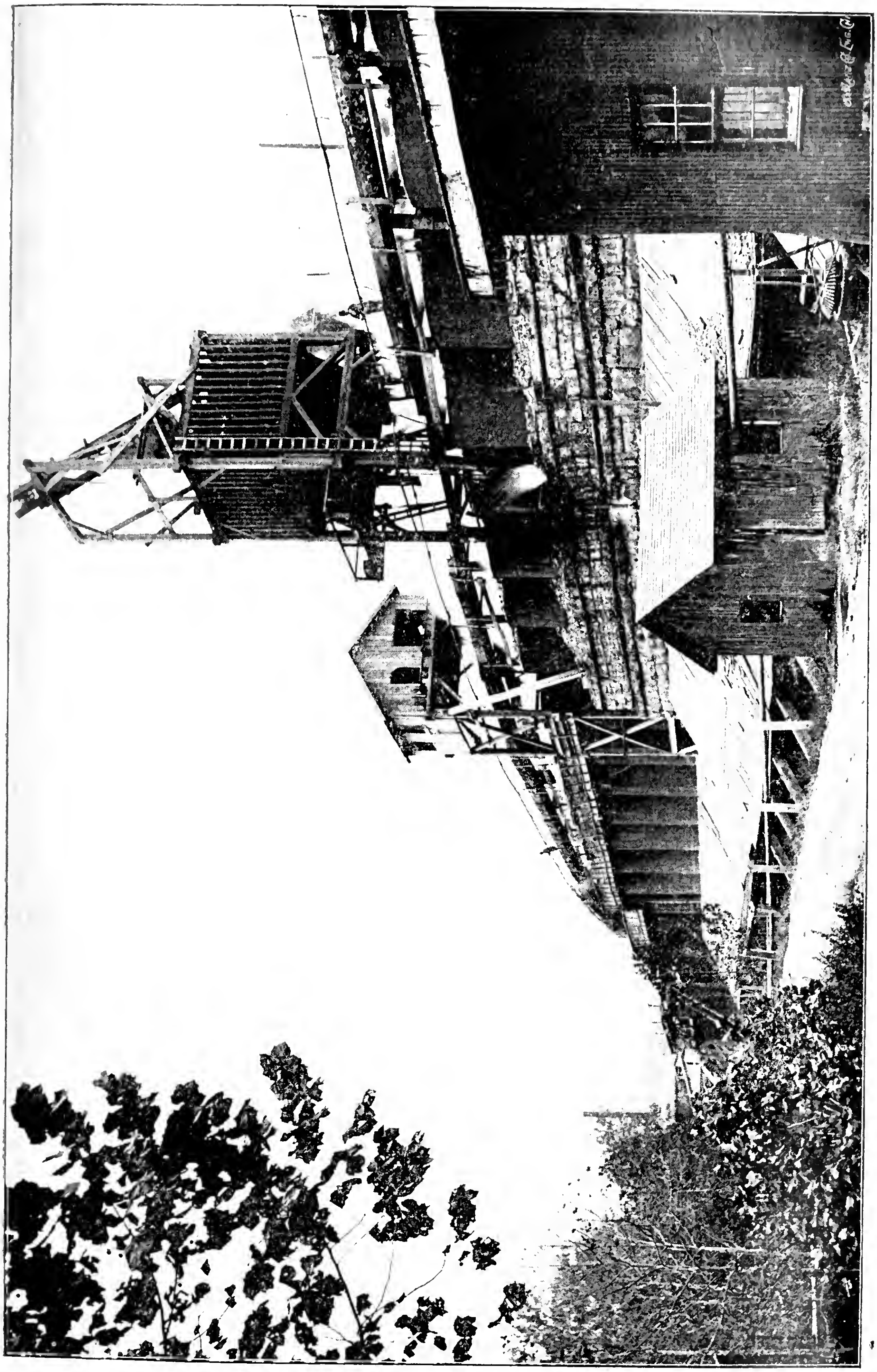


FIG. 145. LOUISVILLE CEMENT WORKS. KILNS AT SPEED MILLS.

while tempering causes slow hardening, still, if the mortar be placed finally in the work within thirty minutes after being made it will in several months attain fully the strength it would have had if used immediately after making.

The amount of water used in making a mortar has a radical influence on not only the rate of hardening, but on the ultimate strength, just as is the case with Portland cement. In making mortar of neat cement the weight of water giving the best results is between 30 and 36 per cent of the weight of the cement. More or less will not make so strong a mortar. In one to one mortar the water should be about 45 per cent of the weight of the cement, and in two to one mortar about 55 per cent.

(e) NOTES ON RELIABILITY OF LOUISVILLE CEMENT.

By Thos. T. Johnston, M. W. S. E.

That which may be called the reliability of a good grade of the cement made at Louisville is especially noteworthy, and the most important of the causes leading to that reliability are worthy of mention.

The practically unlimited expanse of the rocks from which the raw material is taken is to be observed, the mills now located thereon being scattered over an area of 60 or 70 square miles without reaching anywhere near those boundaries which would place the rock beyond easy reach. The thickness of the rock strata is such that no appreciable advantage would result if they were thicker. The rock is disposed so that it is easy to quarry. There seems to be no good reason why suitable raw material cannot be obtained as cheaply as unsuitable material, and it is difficult to see why the manufacturer should have any incentive to use any but proper material. It is very different with the materials from which Portland cement is made. They are not to be had in such unlimited and concentrated quantity, generally speaking, and when they are to be had the constant attention of a chemist is needed to determine that they are suitable.

The raw materials being secured their preparation for the Louisville cement requires simply the always honest, the always unerring crunching of the rock crusher or the sturdy sledging of the equally reliable quarry hand. For Portland cement there must be drying and weighing and analyzing and grinding and other operations involving the faultful intelligence, the carelessness, the capricious avarice of imperfect man.

The raw materials for the Louisville cement being prepared, they must next be burned, and herein again the Louisville cement involves the greater simplicity, the kiln being so simple, the temperature so low, the drafts so readily regulated and the charging of the kiln not needing such special care. With Portland cement the type of kiln best suited for the purpose is a matter of controversy; the method of charging the kiln requires care; high and uniform temperature for a prolonged period is required. With the Louisville

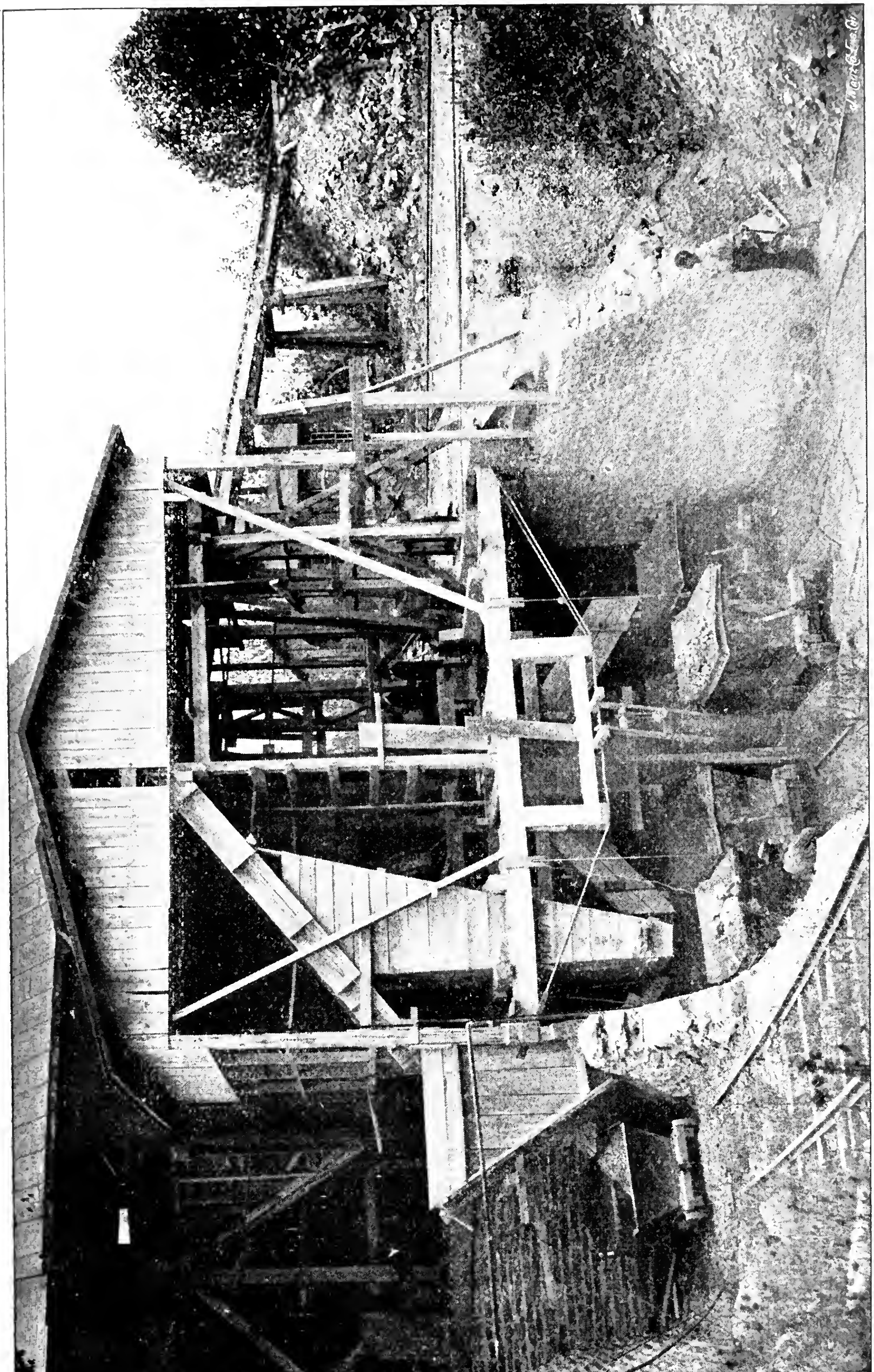


Fig. 146. Louisville Cement Works. View of Stone Crusher at Speed Mills.

product the process is one of simple calcining as in the manufacture of quicklime, while with the Portland product partial vitrification has to be done. The result of the operation with the Louisville product is that essentially the whole contents of the kiln is useful, while with the Portland product a large proportion, sometimes all, is refuse.

The process of burning having been completed the next operation is the drawing of the kiln and the sorting out of material not properly burned, and herein is a wide difference in the care required either in consequence of carelessness and mistakes in sorting or of bad results in the kilns. It is in the kiln that there is more danger of developing a bad cement than arises from other causes. With the Louisville cement the sorting and removal of poorly burned material is an easy thing to do. The good and bad materials appear segregated. With the Portland product it is different, the good and bad material frequently being aggregated. At one Portland cement mill which I recently visited, the product of which mill is ordinarily held to be first class, I watched the man sorting the burnt material. The operator determines the good from the bad both by appearance and weight, but principally by weight. The mill was behind with its contracts and they were trying to make cement in a hurry, largely at the instance of the financial head of the concern. The men had heavy leather gloves on their hands. The kiln was freshly drawn and the clinker hot, so hot, indeed, that the operator held the clinker in his hand but an instant, or a time too short to judge fairly its weight. The result was that the product of the mill was worthless and was rejected from several works. Such a contingency would hardly be possible with the Louisville product.

The sorted material being loaded in cars it is next taken to the grinding machinery, where there is little or no danger of a bad material resulting, either with the Louisville or Portland product, but where much greater expense is involved with the latter. The only question involved is the fineness of grinding, and this is so easily determined that no danger is involved.

In every particular from the securing of the raw material to the finally manufactured product the operations with Louisville and similar cements are far more simple and more free from all the elements that tend to the production of worthless cement, and just to that extent the cement should be more reliable, and should be entitled to more confidence. There has been much written about Portland cement and it has been studied very carefully, and these facts are a result more of necessity than because the Portland cement is the better or more reliable product. Nevertheless, wide difference of opinion exists as to what constitutes a good Portland cement. Only recently two manufacturers were busy in the technical press declaring that each other's products were vicious and worthless, and so on. Perhaps both were right.

At Louisville is the Portland canal, not so called because of the use of Portland cement, which contains the evidence of the reliability of Louisville cement for more than half a century. It could not be

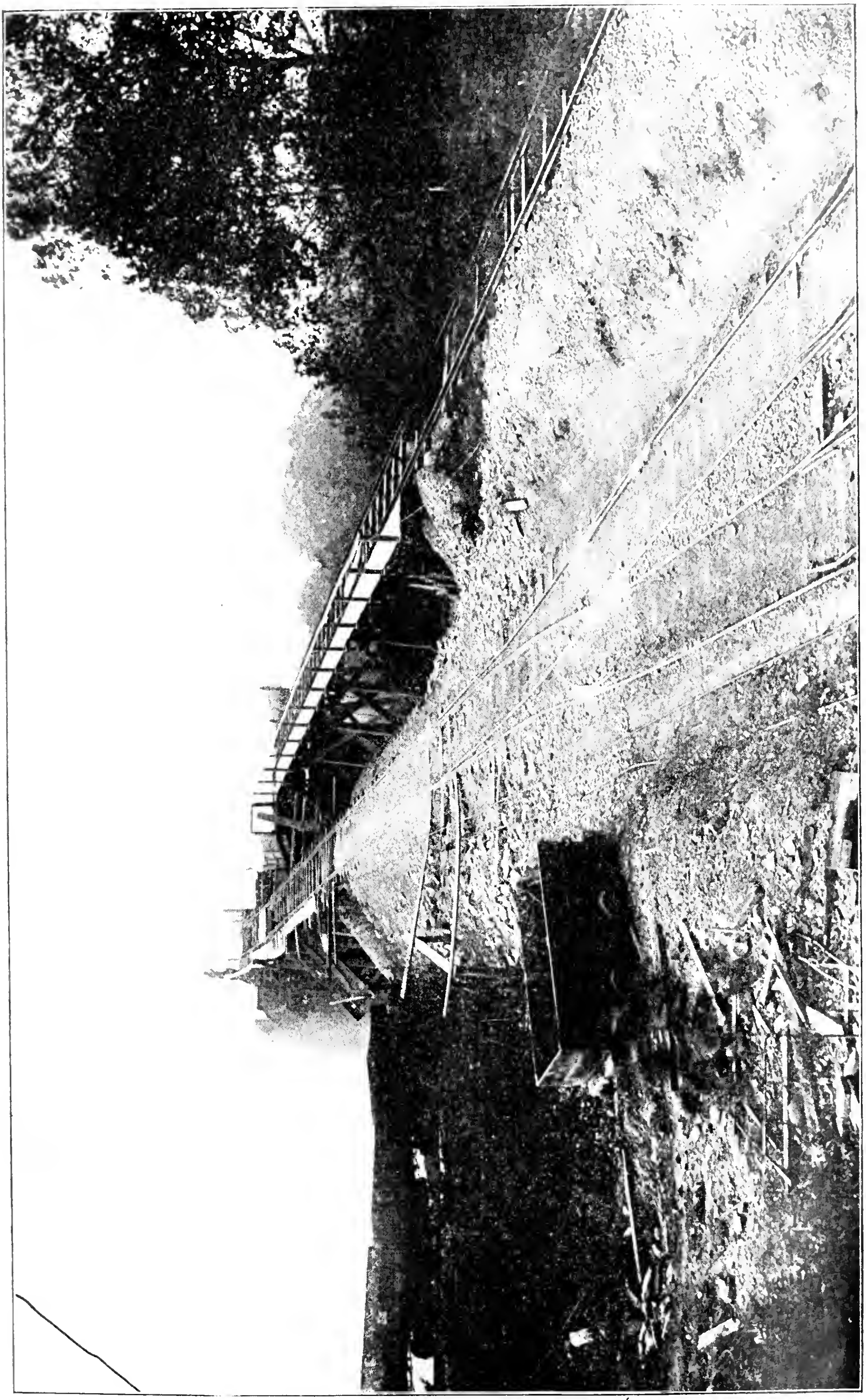


FIG. 147. LOUISVILLE CEMENT WORKS. TRACK LEADING TO SPEED MILLS.

better if the best modern Portland cement had been used instead of the crudely made Louisville cement of fifty years ago. No end of instances exist, extending through many years, in which the cement has proved its reliability when properly made and properly used.

It must not be inferred that, because the cement is made in so simple a manner and involves so little real need for a bad product, that therefore a bad product is not sometimes made. I cannot say that I personally know of any instance of the cement having proved bad, though I have personally conducted the test of nearly 300,000 barrels, involving the breaking of perhaps 75,000 briquettes. Nevertheless, I have rejected quite a little of the cement, not because I knew it was bad, but because it did not quite fill the requirements of a rather exacting specification. If opportunity had been afforded for long time tests of the rejected cement I doubt if there would have been a single rejection. In a number of instances the long time tests were continued after the rejection and they invariably proved the cement to be of high standard. Only a little over a year ago I rejected a large lot of the cement because on seven day tests the neat briquettes checked and cracked. A lot of the cement was laid away for about a month and a large number of briquettes were then made, the breaking to be done through a period of a year. It was found that the cement was the best that I have had to deal with, though rejected. The cement simply needed to be seasoned in the manner usually required of Portland cement, and perhaps not even that, for if it had been mixed with sand it might have done well enough if used fresh.

Quite to the contrary with Portland cement. During the past year I have found much of it unquestionably bad and worthless, in fact in larger proportion than I found the Louisville product, simply failing to meet the high standard of its specification. A Portland cement that is suspicious is very apt to be bad, from the nature of its manufacture; if made with reasonable care it should be of quite uniform product.

However, it is at least conservative to conclude that the Louisville can be, and sometimes is, made bad. If the fact can be determined easily, then it is a factor favoring the reliability of the product. In Louisville is concentrated the manufacture of about 2,000,000 barrels of cement per year. This has justified the establishment there of firms who make a business of testing and examining the products of the mills in large and small quantities. They are well informed on the subject of the manufacture of the cement, are acquainted with the quarries, the methods of burning, the practices of the several mills, and in fact with the expert details of the business. The process of manufacture is so simple that they can easily keep themselves informed as to the history of every barrel from the time it leaves the quarry until the time when it is shipped in the proper inspection marks.

Such complete inspection of Portland cements is not at all practicable, and therefore the Portland products must be less reliable:

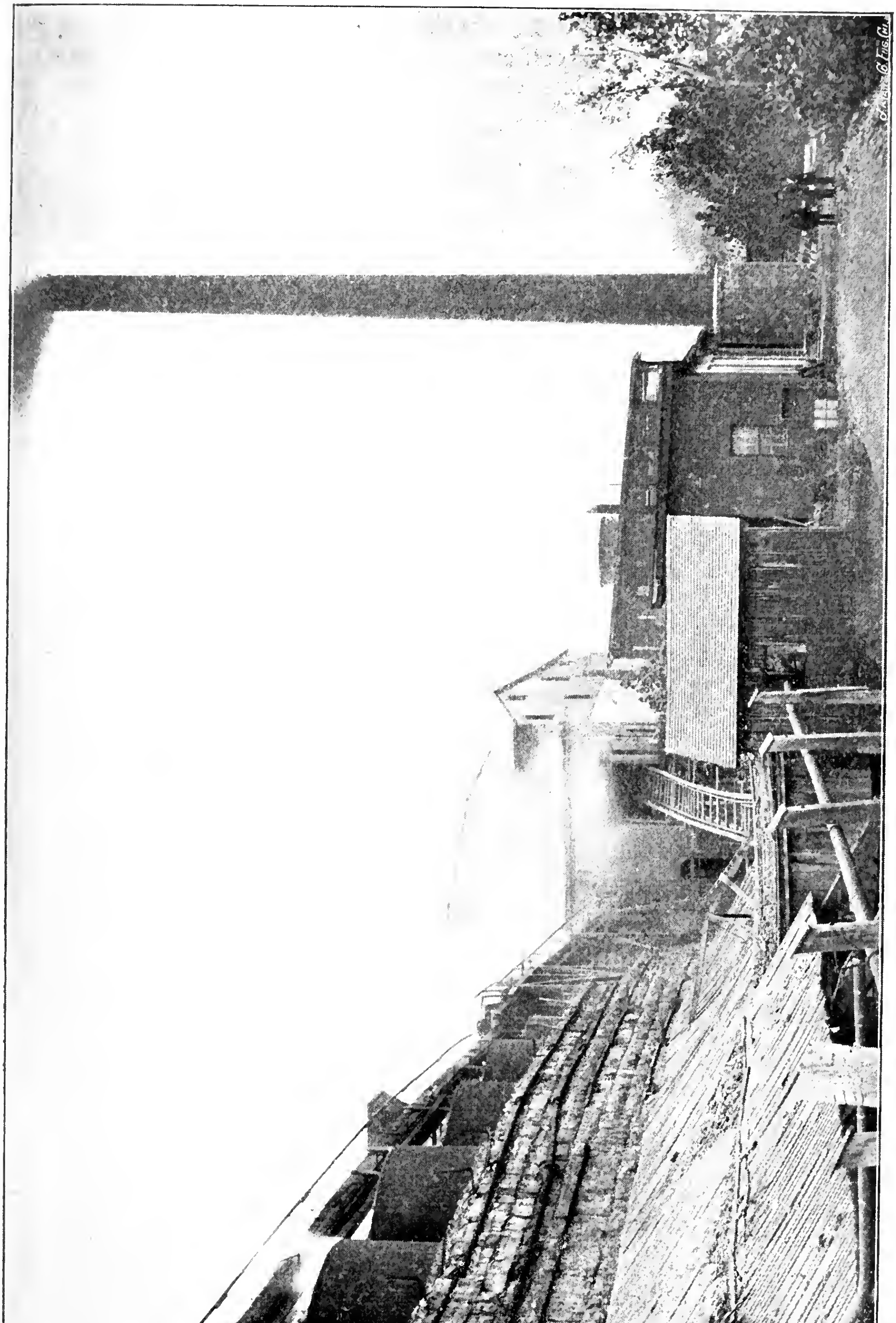


FIG. 148. LOUISVILLE CEMENT WORKS. VIEW OF SPEED MILL AND TRACK LEADING FROM KILNS.

Furthermore, there are more elements of danger connected with the Portlands and many more chances of producing bad cement. Compared with Portland cement, the Louisville product is more reliable because there is less chance of making a bad cement, on the one hand, and on the other hand because it is much easier to detect a bad product.

These remarks may appear to be so axiomatical that an occasion for them may hardly be justified, but it is probable that of the $15,000,000 expended in the United States annually for cement there are several millions expended in the unnecessary use of the high grade cements. Very many instances can be found in which cement is used which costs $2.50 per barrel, where a barrel of the Louisville product at 60 to 70 cents would do just as well. A two to one or three to one Portland mortar is frequently used in masonry, and in concretes, especially in foundations away from the weather, where a two to one natural cement mortar would do just as well, in fact better, because it possesses more elements of reliability.

The Sanitary District of Chicago has constructed many miles of retaining walls in its main channel during the past two years in which Louisville cement mortar was used throughout, and this is said without intending to reflect in the slightest degree on other similar cements used in other walls and which are doing quite as well, and as far as the mortar is concerned I dare say the walls will be standing intact long after every building now in Chicago has ceased to exist. At any rate, there will be an example worth observing, for the walls are above and below a water line. The mortar was made of about 65 pounds of cement (one cubic foot) to each cubic foot of sand. It might just as well have been made with half the quantity of cement, but the cement was so cheap and carelessness of contractors in using cement is so great that it was thought best to use more cement.

It is true that Portland cement can be made good and much stronger than the Louisville product. Strength of a cement, however, has nothing to do with its reliability. The real matter of concern is as to whether the strength, whatever it may be, will persist through indefinitely long time. Long experience has proved that the strength of the Louisville product can be relied upon to do so. There is, perhaps, no masonry structure about Chicago, where compressive resistence alone is involved, in the construction of which Louisville cement mortar would not serve every purpose that a Portland cement mortar would. Excepting in concretes it is equally as good as Portland for resisting the test of winter weather, and if in concretes the cement be set in warm weather the Louisville is probably as suitable as the Portland, due allowance being made in dimensioning to provide for the difference in strength of the two cements. This is abundantly illustrated in the case of a concrete dam builded by the Sanitary District of Chicago on the Des Plaines river, near Riverside.

DISCUSSION.

Mr. President: Is there any new business before the Society? If not, the discussion of the evening will be taken up, which is a discussion of Bedford stone and Louisville cement; the notice says, "By several members of the Society." There is no formal paper on that subject, but the matter is now open for general discussion on the part of these several members, who, I presume, are prepared to give us something interesting. Mr. Johnston, will you please open the subject?

Mr. Johnston: This programme is not exactly in accordance with that which had been laid out by the committee on papers, the paper billed for to-night being by Dr. Maphis, but it turned out that he was unable to be here to present his paper, and in the absence of that paper it was thought that it might be well to present some matter which the publication committee had prepared for the journal on the subject of Bedford stone and Louisville cement. I have that matter with me, and if there is no objection, I will read a part of it.

The efforts of the publication committee have been to make a memorandum of the different points of interest seen in the course of the trip, and also to make some general statement with regard to what was seen. Possibly some members of the Society may not agree with all that is said. If that is true, this would seem to be a good occasion to get at the points of difference. Under the head of stone, referring generally to oolitic stone, the following has been prepared:

(See Vol. I, page 572, etc.)

I think it would be interesting if any of the members present would cite examples of defects in stone, points to be guarded against in the use of it. These remarks will be followed later by what has been said on cement.

The President: It seems that in this particular case it was thought best to deal with the Bedford stone, without any cement. Have any of you gentlemen anything to say about Bedford stone in discussion of Mr. Johnston's remarks? Mr. Gerber, you have had more or less experience with Bedford stone.

Mr. Gerber: I do not know that I can say very much about Bedford stone. I had occasion to use a little about a year ago, and I came to the conclusion that I knew very little about it. I discovered in the course of the examination that, while the stone as a whole is very satisfactory, as we all know, there are some defects likely to crop out that perhaps are not new to most of you, but they were to me.

I had occasion to inspect a piece of coping stone in which there was a seam almost invisible. It had the appearance of a fine chalk mark, and was so slight that I was a little in doubt as to whether it was a seam or not, but careful examination later on developed what would probably be called a mud seam—a fine film of soft material

between the adjacent portions of the more solid stone; the stone was rejected. This was a year ago in October. I went down there again in November, perhaps three weeks after the first visit; the quarry people were somewhat angry because I condemned a very handsome stone six feet square for no apparent cause whatsoever, merely a matter of looks, and while the stone had been taken from the car at the time, it was again on the car the next time I went to the quarry, and was again submitted for inspection as a perfect stone. Unfortunately, it had rained quite severely the week before I came, and when I went over to the stone with the foreman, I recognized it from a distance. The foreman told me it was the same stone that had been submitted to me before. The quarryman reached the stone before I did, and as he stood over the stone he began to scratch his head, and I asked him: "What is the matter with that stone?" "Well," he says, "I don't know where I am going to get another one like it." The rain had opened up the seam so that there was no question about condemning the stone.

I discovered some other marks in the stone of which I am not at all certain, and on which I would like to be enlightened, if anybody has had any experience with it. There were some quite large stone, which were used, that had black marks running through them irregularly, marks that looked as if made with a pretty coarse pencil. Most of those markings that were put into the work were entirely covered up so that I had no fears from them, but whether such a stone on exposure would break up I do not know. As I say, I would like to be informed on the subject. One stone with such marks was rejected and is still sound, but it has been under cover.

The matter of breaking on account of frost is a thing that needs to be pretty carefully guarded against. Out of ten or fifteen cars which were shipped a year ago in November, and left the quarry apparently in good condition and seemed to be dry on the cars when I inspected them, over fourteen or fifteen were broken on arrival, due to the action of the frost, and it was evidently due entirely to the quarry sap, because the most of the frost was in the center of the stone, the stone exploded as it were, leaving an icy nucleus approximately spherical in the middle, while the external portions were cracked off, and were quite free from water.

We all know what crowfoot seams are, I presume; how much they injure the stone is perhaps a serious question. It is, of course, a detriment to the stone; some of them are, however, so minute and the stone so close that it is difficult to say whether they are sufficient cause for rejection.

Glass seams, so far as I am able to observe, when they are entirely filled, are probably no detriment to the stone, but many of the glass seams are only partially filled, and in that case I should think when water entered, that it would be likely to break the stone. I would be very glad to hear the experience of others on these particular points.

Mr. Johnston: With regard to that stone that was fractured. Had you any reason to believe that the stone immediately adjacent to the crack was not as strong as the remainder of the stone?

Mr. Gerber: I should say it was a very sound stone. The crack was a minute line which, after the cleaning, was almost invisible. I discovered it entirely by accident, getting into a peculiar position with reference to the direction of the light. Otherwise, I doubt if I should have noticed it at all.

Mr. Johnston: One of the views which was taken by our photographer at the time of the excursion to the quarries contains a suggestion as to how a crack of that kind might get into the stone. There were two dirt seams starting at the top of the quarry (see Fig. 138, page 599, Vol. I), perhaps six or eight feet apart, and running down the face to a depth of about forty or forty-five feet, that was about the depth of the quarry, but as they went down they tapered off, becoming less and less distinct until at the bottom of the quarry we could not see them from where we were looking. At the time, we were standing at the top of the quarry pit, and they were just rolling over a slab of a stone that was about eleven feet high, four feet thick and probably sixty feet long, probably seventy or eighty feet long, and these two dirt seams came down just to the top of the stone. They were not distinguishable in the stone at all, but in rolling the stone on the side it broke into three pieces right on the line of these dirt seams. Perhaps a little lower the dirt seam would appear as an almost invisible crack, marking the disappearance of one of those dirt seams.

The President: Anything further on this subject? Mr. Parkhurst, let us hear from you. You have had a great deal of experience with Bedford stone.

Mr. Parkhurst: I do not think I can add very much to the information already given, except possibly to say that I have had experience with bursting stone, or frozen stone, rather worse than that named by Mr. Gerber. I think that at least two-thirds of the stone on twelve or fourteen cars were broken instead of now and then one in a lot that was sent, I think in the month of November, from Bedford to the St. Louis Merchant's bridge.

The President: That was due entirely to the stone coming into cold, freezing climate before it was seasoned?

Mr. Parkhurst: That was undoubtedly the cause. It was a stone that had been quarried recently, and rushed to the work with the idea of getting it set, and we had a sudden change of weather with intense cold, I think following rain, and, if I do not mistake, the thermometer went down very nearly to the zero point, and next morning the stones were all gone.

Mr. Kellogg: I have had an experience with Bedford stone very similar to that which Mr. Gerber has given, and among glass seams I have found two kinds that I have really called a glass seam. I have not found glass seams any detriment really to the stone, particularly for a piece of backing. There is a glass seam, however,

that starts in at the face of the stone, and when it gets into the interior it will assume a crystalized form somewhat like sugar. Sometimes it is observable; in that case when water gets into this crystal seam, it will freeze, and the pressure of expanding water will explode the stone. The inspection of stone in the structure should really do justice to both purposes, face and backing, and instead of original inspection for one grade, we might make two specifications for face stone and backing stone. Some defects in the Bedford stone really do not injure it at all for a piece of backing, but it is better to have specifications classifying the inspection for a stone, whether it is to be used in the face or backing at the same standard. I do not believe we are doing justice really to the building material itself. Of course, the quarryman, or contractor, who is furnishing the stone will put up as little as he can for the money's worth. That is his business. The same way, on the other hand, the builder will endeavor to get something as good as he can for the structure for the least amount of money—

The President: Which is also business.

Mr. Kellogg: Which is also correct as a business proposition. The glass seam, as I call it, is not affecting the stones except in looks. I have split off a face stone in which there is a glass seam, and I have found that by taking a hammer and breaking it in the hands, they would break almost any other place except at the glass seam. The glass seam is the defect. The stone must be rigidly inspected, and it is only by experience, I believe, that a man can inspect Bedford stone. It is a difficult stone to pass an honest opinion upon. I do not blame an inspector when he makes a mistake.

The President: There are several gentlemen here with whom I am not acquainted personally enough to know whether they have had any experience with Bedford stone or not. If any of you feel that you know anything on this subject, we would be very glad to hear from you.

Mr. Reece: I have never had any experience with Bedford stone, but with regard to the bursting of the stone from frost, we found that by drilling a hole eight or ten inches into the stone in the center, that there is no further trouble.

The President: Mr. Johnston, have you anything further on this subject?

Mr. Johnston: With regard to the effect and influence of glass seams, I had a little talk with Mr. Wheat, who represented the stone quarry people at Bedford, I believe addressed us there about the time we were leaving, and I asked him how he felt about the presence of crowfeet. He said, with regard to such as they find in the quarries, that he did not think they had any influence upon the resistance of the stone. He said he had never met one that had broken on the surface of a crowfoot. When I put the question to him about the glass seams, he shook his head very seriously, and

said he would rather not have them in the stone. That is an opinion of a quarryman on that subject. I believe there is nothing else.

Mr. Bley: I would like to ask about drilling a hole into the stone to prevent its bursting. Was the hole standing vertical, or was it drilled horizontally?

Mr. Reece: I did not understand.

Mr. Bley: In drilling the hole into the stone, was it drilled in horizontally, or was the hole left vertical so it might fill with water?

Mr. Reece: Yes, vertically.

Mr. Bley: Would it make any difference whether the hole was filled with water? Would it not be better to drill the hole horizontally, so that it would not fill with water?

Mr. Reece: That would depend upon where you leave the stone; that is, what I mean by that is, that the hole was drilled, and the stone turned on the edge, then it would be in the position that you speak of.

Mr. Bley: When the stone is put in place, I should think if the hole was left vertical there is danger of the hole filling with water, and producing the same effect as if not bored.

Mr. Reece: The hole would be filled with cement. That was the common practice.

A Member: I would like to ask how the gentlemen regard the question of Bedford stone being set in the wall in a direction different from its cut?

The President: Mr. Gerber, you and Mr. Parkhurst ought to be able to answer that question.

Mr. Parkhurst: I believe the accepted rule is to allow a stone to be cut in every direction. Practically, after it is taken from the quarry, nobody knows which way the original bed was, if it ever had a bed; that is, which was horizontal and which was vertical in the stone. It cannot be told, I think, generally. In case of the stone which had the blue and the buff colors in it, that might possibly be a clue to the original position of the stone, but otherwise I believe there is no clue.

Mr. Gerber: I beg to differ with Mr. Parkhurst, somewhat. The demarkation between the buff and the blue may be vertical in the quarry, and therefore that would not give a clue.

But the chief thing that I wish to bring out is this: If the stone is perfectly uniform, and you cannot see any marks of stratification, I believe it makes no difference which way it is set. Inspecting the stone that I have already referred to, however, I found a great many that had very decided marks, indicating that the stone was stratified, to some extent at least. I believe where the marking is decided, as is the case in some of the stone, it would be better to lay it with the natural bed horizontally. Where the stratification cannot be distinguished, I do not believe it makes any difference.

The President: Now, will some other gentleman ask a question to bring out some additional points?

Mr. Kellogg: I would like to say something on that natural bed idea. As a builder, I put a clause in the specifications that stone should be laid upon its natural bed. It has been so that it is difficult to decide after a stone is cut and away from the quarry, what is the natural bed. That can be sometimes distinguished and sometimes not. If a stone is strong enough, it is not necessary for the inspector and the contractor to quarrel over it. In other cases, it can be distinguished by a process of making the stone smooth, then wetting the thumb and rubbing it over the surface; I believe I can discover in a great many cases a stratification that is natural. I do not know whether that idea can be developed on every stone, but I have done so in the quarry itself and decided from the knowledge of the workmen afterwards, proving that I was correct. An inspector has to learn something of that. I do not know that I could convey the information how to do it, but there is a difference, and if the inspector will experiment in the quarry upon any stone before him, whether it is the natural bed or whether it is at right angles, after several experiments he can begin to believe anyway that he can detect the difference from the feeling under the thumb.

A Member: I would like to get some information in regard to seasoning of the stone to avoid danger from frost. Where stone is set in thin layers, how long would it take for it to be sufficiently seasoned to prevent any danger of its being injured by frost? Does any one know?

Mr. Johnston: That question I might say was asked Mr. Wheat, and he did not appear to know any time limit to be placed upon the duration of seasoning.

The President: It is simply a question of how long it will take to evaporate most of the sap, according to the season and the conditions.

Mr. Johnston: He stated generally several weeks to be the time necessary to season the stone. There is one question which occurred to me in connection with oolitic stone. Six or eight years ago I had occasion to use some oolitic stone from Northern Alabama, where the deposits are possibly more extensive than in Indiana. The stone was used at Memphis, Tennessee, some of it being used for coping on a weir tank, the stone being laid near the surface of the ground. At the quarry the stones were all a shade of buff, and as cut had a very even appearance, no variation in color, and it was a very beautiful stone, and remained so for some time after it was laid on the wall. After a while, though, it commenced to show marks of fossils, not developing the shape of the fossils, but the stone had the appearance as if originally a great mass of snakes had laid on it, and it being planed off, it left a horizontal cross section of these snakes. I wanted to inquire whether anybody had ever noticed that feature in Indiana stone? Whether they developed those markings after being used?

The President: You can see markings, not of that same character, on some of the coping stone that was used in the elevation of

the Illinois Central tracks down in the Hyde Park district. When the stones were first put on the wall, for several months afterwards they were smooth, and clean, and perfect; then after exposure of one or two winters, they developed those irregularities in the surface.

We will take up the question of cement now.

Mr. Johnston: I presume it would be unnecessary to state anything with reference to the location of the cement rocks. Perhaps it would be enough to occupy attention with regard to the nature of the cement itself.

(See page 610, Vol. I.)

Mr. Johnston: With regard to tests of influence of frost on natural cements, the next journal will contain an abstract from a paper read before the Canadian Society of Engineers, by Mr. Smith, connected with the Magill School at Montreal, who has made quite an extensive series of experiments covering that point. He finds that with natural cement, even if they have had six or seven hours' in which to set, being exposed after that time will develop more strength under the influence of the low temperature than they would have had if they had been in water. He finds with Portland cements it is rather the reverse. He takes the ground (making due allowance for the difference in the strength of the two materials) that the natural cements behave better in frost than the Portland cement. That is a proposition that I think is not very generally accepted, and it probably grows out of the fact that Portland cements can be laid while the ingredients in the mortars are below the freezing point, when the mortar is made; whereas, with natural cements, that can not be done if the hardening or the setting has to take place before it is subjected to the frost.

With regard to the tests of the effect of tempering mortar, I would say, in making these experiments, the mortar was kept continually tempered from the time it was made until the time it was finally put in the molds, and was at all times kept in the consistency suitable for working. It was not allowed to set and then be tempered, and then set again for a while and be tempered. It was kept continuously tempered, the periods of rest being very short, making the test quite crucial.

The results as to the resistance of neat cement and mortar were obtained by making a long series of tests covering a year, and using percentages of water which would make the mortar vary between being as dry as possible and as wet as possible.

The President: Gentlemen, this subject is now open to general discussion. If we are not going to have any volunteer remarks, I will have to call on Mr. Gerber.

Mr. Gerber: I do not think I have very much to say on the subject.

The President: Mr. Parkhurst.

Mr. Parkhurst: I do not feel that the spirit moves me just now.

The President: Cannot we hear something from some of you gentlemen that have not said anything this evening. Mr. Schroeder, don't you know something about this question?

Mr. Shroeder: I do not think we are using very much of it.

The President: In reference to the inspection of Louisville cement, the Illinois Central Railroad has used quite a large quantity of that cement during the last season, and the arrangements of inspection are this: A gentleman in Louisville, Mr. Ball, one of the gentlemen that entertained our Society down there on our last trip, inspects our cement for us at a certain rate per barrel, and he not only inspects the cement in the ordinary way, but supervises the quarrying of the rock and the ledges the rock comes out of, and the burning and the grinding, and then puts his inspection stamp on the different packages, and while Mr. Parkhurst can tell you more about the results of his inspection than I can, I am inclined to think from the thoroughness with which it has been done and the supervision that has been given every individual step from the time the rock leaves the quarry until it comes to us in the manufactured product, that we are going to obtain very good results from it. We have found this: that they only use selected ledges for that purpose when they know this gentleman is going to have the inspection of this cement. They are more careful about the burning, and more careful about the grinding, and to show that they do take extra pains with it. I found by investigation that they charge an extra price on every barrel which they sell subject to this gentleman's inspection, as they claim, to cover the extra cost of handling and storage. That is, they have to keep this material in storage until the results of the tests are arrived at.

Mr. Parkhurst: I might say that I think about 20,000 barrels of cement have been shipped under those tests during this season. I am inclined to differ with Mr. Johnston in one item, however. I have had occasion to look over the reports of the tests of the cement, and while we have a minimum, which is fifty pounds in seven days on neat cement, the range is pretty high, it goes considerably over one hundred pounds on some. I have not made any careful tabulation of the tests to know whether the number that run down as low as fifty is very small in comparison with the total number tested. That might prove to be the fact, but I have noticed a great many cases where it ran down to the limit in glancing over the test. A careful comparison will be made at the end of the season, but we have not had time to do that yet.

Leaving that subject, I would like to ask a question of Mr. Johnston in regard to the statement of the Canadian engineer, or professor. I did not fully understand the statement. I thought that the two statements that were made were contradictory. The first one seemed to be that the natural cement was the better cement to use, and then subsequently that the Portland cement was the better one to use for certain reasons, and those were not quite clear to me.

Mr. Johnston: The Portland cement was better to use when you were actually doing your work in freezing weather, or when the ingredients of the mortar might average up below the freezing point

in temperature; the Portland cement mortar if made under those conditions will harden, perhaps not quite as hard as it would if laid under more favorable conditions. The natural cements must be set before they are subjected to freezing.

Mr. Parkhurst: Did you say the setting was only a few hours?

Mr. Johnston: His experiments involved exposure after being set six or seven hours.

Mr. Parkhurst: Would not the practical result of that be that you would have to use Portland cement after, say, a certain date in the fall in Canada? Would not you expect such freezing weather that it would prohibit the use of Louisville cement, or any other natural cement?

Mr. Johnston: Well, not unless it came on within six or seven hours after the mortar was made. His inference was that there was very much lee-way.

Mr. Parkhurst: As a matter of fact, we have in Chicago, which is not in Canada, of course, but the conditions would be much worse there—we can work in the daytime with water that is not freezing, but along late in the afternoon it will begin to freeze, and freeze all night.

Mr. Johnston: That is dangerous to the natural cements, unless they were protected in the masonry by the stone itself, when the temperature might not fall to freezing point in the course of six or seven hours, even if the temperature was low.

With regard to that statement made first by Mr. Parkhurst, you misunderstood me somewhat. I stated that there was no trouble in getting cements which would stand one hundred pounds in seven days. We have at times had cars of Louisville cement come along which broke under one hundred pounds. We always rejected that, but I am very far from convinced that it was not good cement. I think the one hundred-pound specification could be enforced, and it is good policy to do so.

With regard to the question of the strength attained in seven days, we have made a comparison of some tests on Utica cement, which differs very little, I think, from Louisville cement in its physical characteristics. One set of samples was taken from Blackball and one from the Clarke mill. The Clarke mill will fill a one hundred-pound specification; we have had very few instances below one hundred pounds. The Blackball will not do more than fill a fifty-pound specification, but the series is made at intervals of seven days, twenty-eight days, three months, six months, and a year, and we found that after three months it would stand the test much better. So I think it would probably be found with Louisville cements that go below the one hundred pounds, that after a long time we will find them coming up pretty close to those that harden quickly. I think, perhaps, we will find the same thing with Milwaukee cement. That after a year or so it becomes as hard, as refractory as Louisville cement, although it cannot fill a one hundred-pound specification.

The President: There is one point, Mr. Johnston, that you did not touch upon, and that is in the use of even Portland cement in severe freezing weather; that is, when the weather is freezing when the mortar is actually mixed, and that is the advantages or disadvantages of using heated sand and warm water and brine in the formation of the mortar.

Mr. Johnston: The use of hot water, I believe, has been questioned by the experimenters quite seriously. There is one statement that was brought out in the discussion of the Canadian paper with regard to this hot water, that some Portland cements which had stood the normal tests successfully, even including the boiling tests, had failed by using hot water as a component part of the mortar in freezing weather, while some other of those Portland cements stood all right. The experiments seemed to throw a doubt upon the advisability of using hot water, but they all seemed to point to the advisability of using salt, say two or three per cent, or even more, and in that connection the fact was brought out, or seemed to be brought out by these experiments, that salt acted better with natural cements than with Portland. That series of experiments is quite interesting. It is in the library here, and some of it will be abstracted in the next number of the journal.

The President: If there is nothing further, gentlemen, a motion to adjourn is in order.

Mr. Johnston: If the hour is not too late, I would like to say that I brought over here this evening what I thought might be of interest for the members of the Society to look at. They are some samples of bad Portland cement, showing the way it has acted under the boiling and cold water tests. I do not believe it is very often that you run across such radically bad cases, and it shows the extremes which Portland cement will approach. After adjournment, I will place the packages on the table, and anybody who desires to do so can look at the samples.

XIV.

PARKS AND ROADS.

By J. F. Foster, Superintendent South Park, Chicago.

Read September 16, 1896.

The word park has been enlarged in its meaning so that instead of only indicating, as it originally did, a large area of natural country, well stocked with game, the preserves of some wealthy owner, it now means any piece of ground of any size, with a little or a great deal of the beauty of trees and grass, no matter what other things may be placed thereon or what uses the territory may be put to; so that in name the small city square with an area of only the fractional part of an acre, a few yards of worn out turf and a dozen scragly shrubs and trees, is as important as the great metropolitan open grounds of two or three thousand acres in extent. Between the two extremes lie the many other places dignified with the name of park, within which enclosures are located an inflated balloon or a public drinking place, all kinds of parterres and gardens, bathing beaches, etc.

The broad use of the word is largely responsible for the present tendency to include within our city parks all the attractions which may be found in other places known as parks. It is a tendency greatly to be regretted.

A rural suburban park should be attractive because there can be found all the beauties which nature furnishes so profusely for adorning the earth's surface. It should differ from the natural only as the artificial is required to make the natural accessible and useful. An ideal suburban park would be one in which every part is as attractive as any other part. There should be no prominently objective points, for the assembling of crowds is undesirable—it is what one seeks to escape in coming from the crush of the city streets. The refreshing, restful influence of quiet nature should pervade all places; the satisfying beauties of the country should meet the gaze in all directions and have the appearance of being boundless in extent. All who visit parks give evidence of the desirability of these conditions, though, perhaps, unconsciously. The boy who goes to the park instead of to the vacant lot to play ball, would be puzzled to say why he goes, but he, of course, does so because it is a more pleasing place on account of the surroundings being more gratifying to his senses, though likely he is unconscious of what it is that makes the place attractive. So it is with most of those who come to the parks for other purposes than the enjoyment of the delicious restfulness attending a close association with nature; they all acknowledge, though unconsciously, by their coming that a beautiful place adds to the enjoyment of any amusement. But the ideal cannot be attained in a public park; it can only be approached in private grounds, where there are not thousands of visi-

tors daily, and where the visitors that do come have some respect for the property of the host.

When we hear the word park each of us, perhaps, brings to mind some stretch of river with a beautiful framework of the soft foliage of trees, shrubs and grasses of all shades of green rising from the surface of the water to an irregular, indefinite sky line, or we see again the old path winding through the silent semi-twilight of damp woods, between the mighty boles of the trees rising so grandly all about, the path almost overgrown with the ferns and mosses that carpet the surrounding ground; or, we see the wayside pool, margined with flags and rushes, the water dotted over with the pads and beautiful yellow and white blossoms of the lily, or, perhaps, the trout brook appears to us winding sinuously through the meadow, which is ablaze with the many colored blossoms of the wild flowers. Such scenes, we think, should be found in the parks; but how quickly would this beauty be marred should the reckless city crowds be allowed therein unless an unbearable restraint should be placed upon the people—such restraint that the object for which parks are created would be almost defeated. Yet, on the other hand, the tendency of the times is to give people almost free license to do as they please in a park and try to coax nature to keep the place beautiful, no matter what damage may be done by the heedless and vicious and those only considerate of their own present enjoyment, and these are the great majority. There is in park affairs, as in everything else, a golden mean, and it is this that the designers and those intrusted with the maintenance of the parks are striving hard to find.

The location or selection of grounds for park purposes is, unfortunately, rarely a matter of the adaptability of the site, but is more apt to be determined by the consideration of the effect it will have upon the real estate in this or that location, or, as frequently happens, the land is good for nothing else; therefore it will do for a park. Such being the case, the converting of the swamp, rocks or sand plane, as the site is apt to be, into a park, is not only expensive, but usually attended with unsatisfactory results on account of the want of funds to do the right thing. The designer of a park is asked to take one of these usually unpromising pieces of ground (at least, so they have been in our locality), and submit a plan for its development into the finest park of the country, for you know that is what every community expects its park to be. He must emphasize in his design any natural feature connected with the site which it is desirable to retain, and must obliterate all undesirable features. He must ascertain what trees and shrubs can be best depended upon to make thrifty and permanent growth in the location selected, and what must be done to the earth to make it suitable for plantation. Then he must study the requirements of the people by whom the park is to be used and provide for their absolute wants, and at the same time perhaps open to them unknown pleasures, and teach them to enjoy nature in the quiet way which affords the greatest pleasure. By providing for the wants of the people of the locality

I don't want to be understood as saying that if he finds a number who are interested in prize fighting, or cock fighting, that places shall be provided for such things; on the contrary, parks generally are too much devoted to exhibitions of various kinds, such as match games of ball and cricket, and races of various kinds, the competitors being semi-professionals or club organizations. A park is no place for such contests. The playing of games should be confined to those who indulge therein simply for recreation, not as an exhibition of skill. With such restrictions the playing of games would be confined largely to school children who would be just as well satisfied with any stretch of lawn for their game as with a place especially prepared for it. The same should apply to the riders of bicycles; no racing should be permitted, but ample provision made for the full enjoyment of the parks by those who visit them on wheels, such as broad drives, and, where required, cycle paths, also places where the wheel can be safely left while the owner is otherwise enjoying himself; but the construction of racing tracks seems to me to be diverting the uses of the park from the high grade of reposeful recreation which is primarily its object to that feverish excitement which may be found at the side of the tracks of Roby or Hawthorne. It seems to me that all such things should be avoided, and that a board of commissioners err when they think that they must respond to demands made upon them to furnish a place for every class of amusement. It should be borne in mind that usually those making the demand are so interested in the accomplishment of their object that they have little or no thought to give to the effect a compliance with their wishes would have upon the enjoyment of the park by all the others who visit it. Frequently the park trustees are so interested in pleasing an insistent class that they forget the great primal object of the park, which is not, it seems to me, to enter into free competition with every race track, ball park, merry-go-round, etc., in the locality. But to return to the designer and his task: He, of course, must provide for boating, for driving, for riding, for walking and wheeling, to what extent for each he can only determine after carefully studying the situation and estimating to the best of his ability the probable needs when the population of the territory for which the park is to be the recreation ground has reached its maximum. These wants he designs his park to meet, mingling together as best he can the natural and necessary in his plan, and the nearer he can come to satisfying the desire of all who visit the park to behold the beautiful work of nature, and at the same time make it accessible in all parts with little or no obtrusiveness of walks, roads, bridges, buildings, etc., the more nearly will his plan be a success. An ill-conceived plan for a park will show itself when the park is improved, by the few people to be found in some parts of it and the crowded condition of other parts; the want of distance, of room; the unused drives and walks, and the narrowness of those mostly used; and above all in the evident effort to do too much in the way of making noticeable features such as small, useless hills in an otherwise level piece of ground and the

introduction of bridges where not absolutely necessary. A bridge, like any other structure, or a road and path, is a necessary evil in parks and should be avoided when possible, although when unavoidable, if properly designed, it may be made a pleasing contrast if a good reason for its existence is apparent. The designing of the plantation is, of course, that which needs the most careful attention to detail. Without due regard to what grows successfully in the locality any plantation will be a failure; for a few plants used here and there in the mass of verdure which show a want of satisfactory growth will greatly injure what would otherwise be beautiful effects. Therefore, it is of the greatest importance that in making up the planting lists the designer should make his selection of stock not from some nurseryman's catalogue, but from the information which he may be able to obtain as to the plants which will thrive. The location of his planting in such a way as to screen this or that undesirable view and make in other places the long vistas which are a delight to the eye, with the beautiful soft banks and bays of the ever delightful shades of green to be seen in well selected planting bordering the drives, paths and stretches of water, will show the skill of the master or the weakness of the imitator. Too much importance is given, I think, in most park plantation, to the individual plant. Of course, a beautiful tree is an object to be admired and to delight in at all times, but if the entire park was planted so that each tree would stand out for separate observation you would have much of interest to the person who was looking only at the trees, but you would miss the delightful effects to be found in the massed planting in well designed parks, or where nature's hand only has produced the effect. A plan which will not be criticised will never be produced; but a plan comprehending the entire improvement of the park should be made, carefully considered and approved and then religiously adhered to, otherwise as the improvement progresses the different commissioners will have ideas as to what should be done here and there to meet the wishes of some of their friends, and if they have the requisite force of character they will succeed in getting what they want, and, later, the people will recognize the fact that the park is a botch-potch and then will commence the expensive work of reconstruction. A poor plan, faithfully carried out, is infinitely better than to make the plans piece-meal as the work progresses.

The work of constructing a park includes almost all kinds of engineering work, water supply, drainage, roads, walks, bridges, docks, locks, electric lighting plants, dredging and the moving of large quantities of earth, and in some places shore protecting works. The engineer has much to interest and frequently puzzle him. His greatest obstacle is the strong disinclination of the trustees to appropriate sufficient funds to properly do the underground work as the surfacing of the park progresses, making it necessary to resort to the engineer's abhorrence—temporary work. The great anxiety of a board of park commissioners generally is to show a large area of park surface in grass and plantation and when the matter of drain-

age and water supply is brought to their attention the estimated cost appears so large that the engineer is usually instructed to let the water pipe go for the present and effect temporary drainage at the least possible expense. This, of course, means a general tearing up later which is always expensive and leaves its mark in the lawns and drives for several years. However, it is a question of expediency which, when considered in all its bearings, is perhaps rightly determined when the temporary work is resorted to, for it makes more park area immediately available usually in localities where it is badly needed. The details of park construction do not differ greatly so far as the laying of sewers, water pipe, grading operations, etc., from similar work elsewhere except as all works differ on account of local conditions. It may be well to mention that pipes instead of brick should be used as much as possible, especially in old plantation. Brick sewers drain the ground so thoroughly that trees established under different conditions are likely to die. Much attention is necessarily given to under-drainage for the purpose of rendering swampy land available as lawns. So far as my observation goes, satisfactory results have always been obtained by the laying of tiles three inches and upwards in diameter in lines about one hundred feet apart, with a fall of about two-tenths of a foot to the hundred, the tile laid at a depth of two to three feet below the surface. Some ground in Washington Park which it was impossible to walk over at any season of the year without sinking into the spongy surface over one's shoe tops was thus treated and in less than six months was as firm and dry as any other part of the park. The large meadow, also, in Washington Park, was greatly improved by the same treatment. I have not been able to convince myself that the other great advantage claimed for tiling has been realized in my experience; I refer to the statement made by many that tiled land will not be as dry during a drought as it would have been without tiling.

In the preparation of ground for planting the mistake is often made, on the score of economy, of not properly providing good feeding ground for the roots of plants. The planting of a tree in a hole in the sand ten feet in diameter and three feet deep, filled with black earth, may be sufficient to give the tree one or possibly two years of successful life, but after that the tree will gradually grow weaker and if it don't die will simply exist in a scraggly and unsightly way, a painful evidence of the want of proper treatment. A tree should have at least a depth of three feet of mellow vegetable mould covering a distance of twenty feet all about it, to produce a vigorous growth. If the natural soil is sand it must be covered with the proper material brought in for the purpose. If, on the other hand, stiff clay is found on the ground, it should be dug up to a depth of two feet at least, and after having been exposed to the sun and frost in a loose condition for a year or two, tempered with sand and manure as required; then plants may be safely put into it. I don't want to be understood as saying that trees will not live unless treated in this manner, but I do say that such treatment will produce results so much superior to those obtained by simply planting trees in

small holes filled with earth that any expense incurred in making the proper preparations will be more than justified. The great beauty of a park is to be found in its plantation and if that is not done in the beginning in such a manner as to produce and maintain a thrifty growth, it will always be unsatisfactory, for it is impossible to revive trees once injured by want of proper nourishment, no matter how much may be spent in the effort. Therefore, the most important thing in the work of park improvement is proper preparation for producing the best plant life that the climatic conditions will permit. For lawns I have found that about eight to twelve inches of earth is sufficient, depending largely on local conditions.

The designing of the necessary structures in a park should be given into the hands of the very best architects, for the best is surely one who realizes that "art is fitness," and he will not in designing the building have more in mind the erection of a monument to himself than the fitness of the structure for the uses to which it shall be put and the appropriateness of design to its environment. The architecture should be designed to fit the landscape—the park design should not have to be made to fit the building. A mistake liable to be made in park improvement is to assume that a building not provided for in the original plan is wanted, and without careful consideration and perhaps modification of the plans it is located at some point of vantage, as it is said, but really to the utter undoing of some of the most beautiful features of the landscape as designed. I must again say that the approved plan for the laying out of a park should be as unchangeable as the laws of the Medes and Persians are said to have been.

The construction of walks is usually a question of no little perplexity. The comparatively large area required makes it important to keep the cost as low as possible. As much care should be given to the form of a walk, the material used, the foundation and the drainage, as is bestowed upon roads. For the majority of walks in a park it is desirable to use material of a color that will not be in striking contrast with the grass and the foliage of the trees and shrubs. A material should be used which will not have the appearance of being too hard and stiff, like concrete or cement, except in some places where such a walk is absolutely necessary. My experience leads me to prefer a properly prepared clay and lake shore gravel surfacing for walks. Its color is satisfactory, and, if the gravel is fine enough, it will make a pleasant walk. A layer of this surfacing one and one-quarter inches thick, after rolling, placed on three inches of crushed stone or bank gravel, will make a durable walk. In wet weather, if used much, the surface may become muddy if care is not taken to keep it well dressed with fine gravel. The gravel should all pass through a screen (one-eighth inch mesh), and be mixed with a yellow clay which has been pulverized, as carefully as cement mortar is mixed, the quantity of clay being slightly less than the voids in the gravel. After laying and rolling, the surface of the walk should be dressed with fine gravel, the layer being simply enough to cover the surface. Crushed limestone, if properly

used, makes a good walk, but its color is very undesirable. Crushed granite surfacing makes a durable walk and a satisfactory color can be obtained, but the particles of granite are so very sharp that fine thin-soled shoes are very quickly injured upon it.

The construction of roads is always a problem, for the cost is comparatively large, and the least expensive materials and methods are not always, if ever, the most economical. Each year's experience is apt to convince one that former methods can be improved upon. In park roads a question of great importance is the color of the surfacing material. The drives on the interior of the parks, particularly, should be as inconspicuous as possible and neutral tints are therefore to be desired in the surfacing materials. This, of course, applies to boulevard drives also, but is not so imperative as in park driveways. The character of the surface upon which the road material is placed, of course, determines the possibility of constructing a good road of any material. Sand properly and evenly compacted makes a satisfactory base, but no little care is required to put even sand in good order for receiving the material. It frequently happens that just before entering upon the construction of a road the ground is opened for various purposes by contractors who are not interested in the foundation for the road, and therefore simply fill in the trenches without any care as to puddling or ramming. These trenches should be partially reopened for the purpose of thoroughly puddling and back-filling. Specifications for constructing roads generally require that the graded earth shall be rolled until no settlement occurs under a ten or fifteen ton steam roller. If this is faithfully carried out, with all trenches properly puddled and all sand that has been removed within two years, either in the trenches or on the surface, thoroughly wet while being rolled, a foundation practically of an unyielding character may be obtained in sand. Puddling seems to have several definitions. Some think it has been successfully done if a trench, after having been perhaps two-thirds filled with earth, is flooded with water and then the remaining filling placed. This, of course, is better than no attempt in that direction, but well rammed back-filling is better than that; indeed, with material which water will not break down ramming is the proper treatment, the material rammed in layers not exceeding six inches. Proper flooding of trenches consists in throwing all the back-filling into water; if otherwise done it is not successful. It is not always practicable to do this on account of the necessity of having sewer trenches partially filled before the cement sets. In such case the first eighteen inches or two feet of filling should be carefully rammed. But, how seldom is this done? The matter of draining the foundation should not be overlooked. If the earth for several feet in depth and for some distance on either side of the road is sand and the road not materially lower than the surrounding surface, no under drainage will be necessary, but with a foundation of clay or vegetable mould it is desirable to provide some means to carry off the water which would otherwise accumulate in the foundation and by being frozen heave the road material, break the bond

and form a spongy place in the road, greatly to its injury. Instances of this may be seen in many roads in the western part of the city, where the road material is placed on clay. When sewers have been constructed and catch basins built at the side of the drive at intervals of about two hundred feet, the making of small trenches in the earth leading to openings in the catch basins and filling them with coarse stone will overcome the difficulty unless the ground is very soggy, in which case lower drainage by tile will be required. If the methods above enumerated are carried out one may safely build the road upon a foundation so prepared, with the assurance that little, if any, settlement will occur.

The form of a road should be carefully considered in connection with the material to be used. A macadam or gravel surface should have an inclination towards the gutter sufficient to carry off the water quickly, but not so rapidly as to make gullies near the gutter. For drives that are not subjected to heavy traffic and are to be kept in good repair, a crown of about two per cent of the width of the road is about right, although for narrow drives this should be somewhat greater, and for drives over fifty feet somewhat less. Drives used for all traffic and not having the best of care should have two and one-half per cent crown at least. For hard surfaced roads, such as wooden blocks and stone blocks, brick and asphalt, the crown should decrease from that above stated in the order named, asphalt having, if properly laid, about one and one-quarter per cent of the width. The crown named is that which I think is desirable at the catch basins; at the summit, when the grade of the center of the drive is level, it would have to be less, except the center of the drive rises with the gutter, which is not desirable. Catch basins should be placed at intervals not exceeding two hundred feet. The catch basins should be placed outside the driveways in the lawn or walk, as the case may be, thus avoiding the inconvenience and danger of a cover where horses travel. The inlet to the basin will have to be through the side of an iron cover or through the curbing and wall of the basin. There are many ways of doing this and many patterns of covers. It is of little consequence just how it may be accomplished; the main thing is to have it done in a durable manner. The curbing should stand about six inches above the gutter at the catch basins, and three inches at the summits of the gutter, to make the best appearance. On business streets, where the walk extends to the curb line, three inches may be added to these heights. The upper corner next to the driveway should be cut to a circle, with a radius of one-third the thickness of the curb; an axed or bush-hammered surface is the most pleasing. The depth of stone curbing should be not less than twenty-four inches in sandy earth; in clay not less than thirty inches; that is, if not rising above the gutter more than the figures above given. Twenty-four inch curbing may seem quite shallow, but I have had excellent success with it in sand, when carefully set on good stone blocking not less than six inches thick. On roads where heavy wagons are likely to back up against it the most economical and satisfactory material to use for curbing is gran-

ite, although the original cost of the stone is fully double that of limestone in this locality. I do not think any other kind of stone should be used on city streets. In suburban streets and boulevards, where there is little likelihood of its being injured by wagons, concrete is very satisfactory. If properly made it is durable and is satisfactory in appearance, though the surface should not be troweled. If proper care is taken in the foundation it is not as likely to settle irregularly as natural stone curbing. On sand a bed of well rammed cinders six inches in thickness and on clay twelve inches in thickness, I have found to make a good bottom. The concrete gutter either in connection with curbing or not, is unsatisfactory. If on a street where there is heavy traffic it will be broken down on the edge and soon look badly. If placed where there is not much traffic it may endure, but is unsatisfactory because the least little dirt shows so plainly that it must be cleaned every day or it looks as if badly neglected; particularly does this objection apply to boulevards. A gutter is desirable on streets where the grade is so great that road material will be washed out or where horses are likely to stand at the curbing and paw holes in the road. Other roads look better without gutters. When gutters are necessary bricks and granite blocks are the proper materials, laid with as much, if not more, care than when used as a pavement. Of the many kinds of road materials used each has qualities to recommend it for certain places and conditions. The stone block, of which there are many kinds, is probably the most durable pavement, and in streets where there is a great deal of very heavy traffic about freight houses and other places where noise is not an insuperable objection this is undoubtedly the best pavement to use. The best block pavement is obtained by laying the block on a cushion of sand about two and one-half inches thick, resting on a concrete base; the only reason for the sand being so thick is to take up unevenness in depth of blocks. The blocks should not be too wide; the smoother surface can be obtained with blocks from three to four inches in width and nine to twelve inches in length. For heavy traffic they should not be less than six inches in depth; the joints should be filled with screened lake gravel of a size to be determined by the thickness of the joints between the blocks, which depends upon the specifications under which the blocks are cut. The joints, however, should not be more than five-eighths of an inch at any point. The gravel should be well prodded in and the joints filled with paving cement. The proper ramming of the blocks is of great importance. There are many blocks called granite which are not granite, but frequently the stone is just as good. There are some hard sand stones which make an excellent pavement, not being as slippery as the harder stones, but, of course, they wear much more quickly. As a general proposition, the harder the stone the better. Probably there is a greater variety of stone used for paving in Chicago than any other city; five, or perhaps six, kinds of stone used are excellent, one nearly as hard as the other, though strictly speaking three of the best kinds used are not granite.

though accepted under specifications calling for granite. The great objection to stone block pavement is its being noisy and very disagreeable to ride over, and, next to asphalt, the most slippery of pavements. Its life on a suitable foundation, where openings are not frequently made in the street, is somewhat conjectural, but it may be counted on for twenty-five years under the ordinary business traffic, with repairs not exceeding ten per cent of the original cost for that period. Asphalt pavement needs no description; every one knows that it is a sheet of a certain kind of bituminous matter spread over a concrete base. Properly made its durability is next to stone blocks, and if the blocks are not of the best stone it will out last them. It is easy to keep clean; it costs much less than stone blocks, and is not very disagreeably noisy. For ordinary city business streets, and residence streets that are not to be well cared for and are not used to a considerable extent as a pleasure road, asphalt is probably the most economical and satisfactory pavement. From a sanitary point of view and for the ease with which it may be kept clean it is undoubtedly superior to any other kind of road surfacing. Its drawbacks are its slipperiness, and, on residence streets, the clicking sound caused by fast moving horses. It will probably endure under the traffic of a business street when it is not excessive for fifteen years, at least, before renewal is necessary. The cost of such repairs as may be required during the fifteen years, aside from such openings as may have to be made in the street, will not exceed eight per cent of the original cost. It can be laid for about forty per cent of the cost of stone block pavement. The wooden block pavement has many forms of construction and many kinds of wood are used. The round cedar block has nothing to recommend it except its small cost. The blocks so soon become worn on the edges that the road, except as to hardness, is much like cobble stone, and after getting in this condition the blocks are very quickly pounded to pieces where there is much traffic, either of light or heavy vehicles. The old Nicholson pavement, in which pine or other wood blocks of rectangular form were used with one inch spaces between the courses filled with lake gravel and paving cement, was better than the cedar block only in the fact that only two edges of the blocks would quickly wear down and expose the blocks to the pounding process which quickly demolished them. Both the cedar blocks and the Nicholson pavement have heretofore usually been laid on plank laid in sand on the natural earth foundation, supposed to have been well rolled. The result was, of course, what could only be looked for, rapid settlement into an uneven surface, and the blocks quickly worn out if there was any traffic to speak of on the street. A wooden pavement, perhaps more than any other, requires a firm foundation, and, except under uncommon conditions, the blocks should be laid on a one inch cushion of sand on a concrete base. The blocks should be five inches in depth, three inches in width and about twelve inches long, laid closely together with expansion joints here and there to take up the swelling of the wood;

just what may be required in this direction must be determined in each case, the condition of the wood and its character will suggest the precautions to be taken. Pine blocks of the above named dimensions, laid fairly dry, with joints rather loose, but till the blocks set against one another, with the joints afterwards swept full of fine sand, and paving cement poured over all, did not swell sufficiently to heave the pavement at all. On the other hand, oak blocks laid in the same manner have expanded seven inches in twenty feet. Expansion should therefore be provided for at short intervals in the pavement or the blocks will creep more or less, and in doing so lose their even surface, causing quick wear. The question of what kind of wood is the best is one difficult to answer. In the first place any wood should be treated by some of the best methods for preserving it. If properly done this will dispose of the matter of decay in making the selection. Oak will probably wear longer than any other wood obtainable in this locality at a reasonable cost, but it becomes much more slippery than pine or cedar. The pavement may be greatly protected from wear by covering it once a year with a good dressing of paving cement and rather coarse, sharp sand at a cost of not exceeding ten cents per square yard. Where the pavement is not greatly used by heavy wagons and when the traffic is not excessive, this one dressing a year will double the life of the pavement, and at the same time furnish a most desirable surface to drive over. If kept surfaced in this way the objection to oak on account of its being slippery would disappear. Good pine, all things considered, is probably the best wood except where used largely by heavy wagons, when oak should be used. The life of wood block pavement is, as the foregoing will indicate, rather indefinite. Without treatment for preserving the wood and not kept dressed with tar and sand, decay will destroy it in from four to six years, according to the wood used. Much heavy traffic will wear out pine in three years, or less; with a large light traffic it might last four years before having to be renewed. Oak would probably last four and five years, respectively. As to the preserving of the blocks: I have some specimens of blocks treated for preserving them against decay which are vouched for as having been in a pavement in a well used street for over twenty years, and the blocks are in good condition to-day. The wooden block pavement is the most quiet of all pavements; it can be very quickly relaid when necessary, and, next to a macadam or dirt road, is, when in good condition, the pleasantest to drive over; but unless it is laid with the greatest care and kept in good order as indicated above, it has only its noiselessness to recommend it. The cost of pine block pavement would be about thirty per cent of granite blocks. The cost of keeping it in good repair would be about fifteen per cent of the first cost per annum. A concrete base, such as has hereinbefore been referred to, should be at least six inches thick, and like all concrete, cannot be too good, though in many places Portland cement will not be a necessity.

The macadam road is the most pleasant to ride upon of any with

the exception of a dirt road in its best condition. The thickness of the material used depends upon the use to which the road is to be put and the character of the foundation. The necessity for careful preparation of the foundation for any road has heretofore been noted, and in considering the different kinds of roads it is presupposed that the foundation is properly prepared. On a sand foundation macadam road material should be for heaviest traffic fourteen inches in depth; for ordinary heavy traffic twelve inches; for light traffic, such as boulevards and suburban residence streets, nine inches; for park driveways eight inches; on clay or loamy foundations the addition of about two inches to these depths is desirable. A macadam road should not be considered for heavy traffic except where the cost of constructing a better road cannot be met. In some cases it is impossible to avoid it as a temporary expedient; it can only be justified under some such conditions. The under ten, nine, six and five inches respectively of the thicknesses named may be made of the cheapest stone obtainable, which will not crush or grind up under a fifteen ton roller, or disintegrate through the action of the elements. It should be crushed into pieces closely approximating two and one-half inches in their greatest dimensions, and thoroughly rolled in layers not exceeding six inches in thickness. With proper foundation this will make a road as satisfactory as the more expensive method of using in the first course large stones, placed by hand base down, known as the Telford road. There may be some cases when such a method would produce better results, but they do not frequently occur. For the surfacing of the road—that is, the upper three or four inches, as the case may be, different kinds of stone and gravel are used. The most durable and cleanest is crushed granite and trap rock, but either is much more expensive, both in first cost and cost of maintenance, than good, hard limestone, but under certain conditions the extra cost is justified by the much better results. On a boulevard drive used extensively a road surfaced with granite or trap rock will not wear as rapidly as it would if limestone or gravel was used, which results in not having to resurface it frequently, in not having to clean it so often and in its not being so muddy in wet weather. These qualities are very desirable and fully warrant the extra expense on such streets as Michigan avenue, where there is a very heavy drive. In outer boulevards, where the driving is not so constant in all kinds of weather, a limestone surface is probably the best, cost being considered. In parks limestone is objectionable on account of its color, therefore, a good bank gravel is desirable. The crushed gravel that is now being obtained for the purpose is practically limestone discolored and is nearly as clean and as durable as the stone. In some parts of the country there is a grayish blue limestone which makes a good surfacing for park roads, the color not being objectionable. Trap rock and the gray granites would be excellent for park roads, but if good gravel can be obtained it is so much cheaper and so nearly as durable for the purpose that the use of granite is hardly

justified. The three of four inches of surface material should be crushed to as nearly a uniform size as possible. For the traffic roads the pieces should be one and three-quarters to two inches in largest dimensions; for the other roads one and one-quarter inches. It is a mistake to use this material too coarse on roads to be used by light vehicles. With stone larger than one and one-quarter inches the road will surely become rough on account of the pieces being kicked out here and there by fast moving horses leaving slight depressions, which are not only unpleasant to ride over, but help to wear out the road, keeping it soft by catching and holding the water thrown on the drive by sprinkling wagons and rains. This surfacing material should be rolled without stint and only so much fine packing material added as may be absolutely necessary. All the fine stuff added is sure to come back to the disadvantage of the road in the shape of mud. The best material for packing the granite is screened bank gravel and only about one-half an inch of this should be used. It should be borne in mind that a roller never packs a new road; it simply presses the material together so that it will keep in place until the wheels of the vehicles passing over complete the work; therefore, it is a mistake to keep putting in fine packing material, hoping to complete the work with a roller; mud only is being added. Of course, with trap rock and limestone fine stone of the same kind is used for packing. Rolling is the most essential work in the construction of a road and should not be slighted; in all cases it should continue on the lower courses until no depression is made, and on the upper or finishing course until it "mortars up," or becomes covered with mud. A liberal use of water helps the matter along very much. The macadam road, even when surfaced with the hardest stone, where used greatly in the continued wet weather of open winters and in the spring and fall, will at times become muddy and disagreeable, but this condition will likely only exist for a small part of the year, and at a time in the year when there is little, if any, driving for pleasure. On the other hand, it is so much more desirable than any other road during the driving season that people generally, cheerfully put up with the mud as an unavoidable evil, feeling that they are more than recompensed for the discomfort when the road is in good condition. This justifies the use of macadam roads on all boulevards, even those where the driving is very heavy like Michigan avenue, or on the residence street where care will be given to the road. If properly cared for a macadam road is the most satisfactory of all roads for all places where people drive for pleasure to any extent, except where there is considerable traffic with heavy wagons.

Limestone macadam roads properly built will cost, for the eight inch road, about twenty per cent; nine inch, twenty-two per cent; twelve inch, twenty-five per cent; fourteen inch, twenty-eight per cent of the cost of granite blocks; the granite or trap rock surfacing will cost about twice what the limestone does. Gravel is perhaps fifteen per cent more expensive than limestone. The cost of a nine

inch limestone road, as the work is done in the South Parks, is about seventy cents per square yard at present prices.

The duration in good condition of a granite surfacing where the drive is heaviest, on the north end of Michigan avenue for instance, is three years; the cost of renewal at present prices with the best material is not less than forty cents, making the annual cost of renewal of surface about thirteen cents. The annual cost of maintaining a drive under the conditions such as exist on the north end of Michigan avenue, will not be much less than fifteen cents per square yard, there being more or less patching required each year. A stone or gravel surface under the same conditions would have to be renewed in two years; the cost would be only about half as much, but its condition would be unsatisfactory most of the time.

An equestrian road may deserve mention: Tan bark, sand, gravel and clay, have been used for this purpose, placed upon firm stone or gravel bases or on spongy earth. In the South Parks the most satisfactory results have been obtained by properly shaping and draining ordinary black earth (not too clayey) and covering it with a thin dressing of the cleanings from macadam or gravel roads, just sufficient to make a surface into which a horse's foot will not sink. This makes a springy road, very enjoyable and not hard on the horses. In very wet weather it becomes soft, but properly drained is in a few hours in good order again.

The maintenance of parks is often not given proper consideration by the authorities having the matter in charge. A park and a system of boulevards may be constructed in the best possible manner, but a few years' careless maintenance will cause a wonderful transformation. The first duty of park trustees should be to see that the improvements made are maintained in the best possible manner. It may cost more to do the work properly, not so much more, however, as might be imagined, but no matter how little may be spent in maintenance, if all things are not kept in good order the people who furnish the money will justly criticise the expenditure. On the other hand, there is never any questioning the expenditure if all interested can at all times show the park to their visitors with no excuses to make as to its appearance, but with pride call attention to the cleanliness of the walks, drives and lawns and to the thrifty and well-cared for trees and shrubbery. This, however, owing to the want of proper attention being given to the necessaries in the beginning, is often very difficult to attain. The first requirement is plenty of water, but on account of the cost of a suitable plant for its supply it is frequently omitted until everything else is provided and only put in when burnt grass and dead trees force the trustees to a realization of its positive necessity if they expect to keep the park in a presentable condition. An illustration of this may be had in comparing the fresh, green appearance of everything in Lincoln Park this summer and the dried up grass and trees of a few years ago. With plenty of water at a good pressure, the keeping of the lawns and plantation can be cheaply and effectively done; without

it nothing satisfactory can be accomplished at any cost. Another thing that is too apt to be neglected is the plantation. It will not do to pay no attention to a piece of planting because it has been successfully done. It must be thinned out here, new stock put in there, old shrubs removed and replaced with young stock, and this must be kept up constantly or the plantation will mar instead of adorn the park. All things must be kept in the best possible shape, whatever the cost. It is far better to do this, making improvements less rapidly than it is to make extended improvements at the expense of the improvements that have been made. A board of park commissioners that carefully maintains the area improved will be furnished with what money may be necessary to make further improvements as they are demanded. Some years ago I read a statement made by Frederick L. Olmsted that the qualification most to be desired in a park superintendent is efficiency. I thought that was absurd, as, to my mind, it seemed that economy was a prime requisite; but as I get more experience I am satisfied that it is better to have efficient work with poor economy than indifferent maintenance with excellent economy. Of course, it does not follow that both are not to be had. A park is only what its maintenance makes it. To properly fill its mission it must be inviting; to be inviting its roads and walks must be clean, in good repair, properly sprinkled, and the edges nicely trimmed; the lawns must be kept well clipped, fresh and green, with no places where the grass is worn out; the trees and shrubbery properly watered and renewed when necessary; all buildings for sanitary and other uses must be in good order, well painted and in repair, and the lakes where boating is permitted must be kept clear of weeds and the water changed frequently to prevent its becoming stagnant. This, with all the other little matters pertaining to the work, requires constant vigilance on the part of the person responsible for the work and cannot be successfully accomplished without the expenditure of considerable money. The cost per acre of maintaining parks varies greatly, according to the use made of the park and the number of visitors per acre. It ranges from $60 per acre to $600 per acre per annum in our largest city parks; probably the average would be about $125, including policing and all expenses. The cost of maintaining boulevards is also variable. Michigan avenue, for instance, costs yearly about $7,000 per mile, and Grand boulevard $6,500 per mile.

The cost of the improvement of large suburban parks will perhaps average $3,000 per acre.

Is all this expense of creation and maintenance justified? The answer must be in the affirmative. From purely a financial point of view parks and boulevards are a good investment for a community. Much attention has been given to this question in Boston. A reference to the annual report of the park department of that city for 1805 will show that the value of the land in the vicinity of the Back Bay Park improvement trebled in thirteen years, while the balance of the city increased only eighteen per cent. The increased taxes on the land on account of the increased value during that

time was $2,000,000, which more than covered the cost of all improvements. They find that instead of increasing the rate of taxation the location and improvement of parks so affect the value of adjacent land that the rate may be reduced and still the tax levy be enough greater than before to provide for the maintenance of the parks. An investigation into the relative values of land in the neighborhood of the parks and boulevards in Chicago will undoubtedly show the same results. Property fronting the large boulevards is about double in value that on the next parallel streets, which, but for the boulevard, would probably be just as good streets as the boulevard would have been. That increased value alone would add much to the amount of taxes to be collected, with no increase in rate, but when attention is given to the fact that all property within at least one-third of a mile of the parks and boulevards has improved in value much faster than other property in the city, the cause directly attributable to the park improvements, it must be acknowledged that for the whole city the establishment of the parks has been a good business enterprise. But, considered from the other point of view, what do we have to pay for the privilege of using the parks and boulevards? The rate of park taxation on the South Side last year was 34 cents of tax on each $100 of valuation. The valuation of property by the assessors averages about one-tenth of its real value, so that a person owning a house and lot, the real value of which was $10,000, would pay for park purposes $3.40 tax per annum. (The rate is somewhat heavier on the West and North Sides.) Can anyone call that a burdensome tax for park privileges for the owner of such a place? Parks must be good things else all the great cities of the world would not be acquiring so much land for the purpose. Paris and London not only have large city parks, but have also their great woods or country parks, or reservations like the Bois de Vincennes and the Epping Forest. Boston is taking steps in the same direction through its Metropolitan Park Board. The national government in its reservations of large tracts of land as national parks, has taken more advanced ground than any other country in this line. The Yellow Stone Park alone has an area of 3,755 square miles, more square miles than Chicago has acres of parks. Notwithstanding the fact that Chicago has a park system of large possibilities, it does not equal that of many of the larger cities of the world, and as no one for a moment thinks that it has reached its growth, it would seem the right thing to do to make preparations now for park privileges which will be demanded when the city shall be thirty years older. There is one feature Chicago has possessed by none of the great cities of the world. It stretches for twenty-one miles along one of the most beautiful bodies of water on the earth. This water front can be put to no better use than as recreation ground for the people. Already a start has been made by locating Jackson and Lincoln parks on the lake, but this is only a beginning. I expect to see an unbroken stretch of parks and boulevards along the lake shore from South Chicago to Evanston. Should this be liberally carried out, Chicago will have park improvements commensurate with her present and prospective greatness.

XV.

PARKS AND PARK ROADS.

By H. C. Alexander, Superintendent Lincoln Park, Chicago.

Read September 16, 1896.

The park is an evolution from the forest clearing of the village community, in which a few trees were left as homes for the dryads or tree gods, and which served at once as public assembly, burial place and an open air temple. With the development of the village into the city the clearing became a common or passed into the possession of the chief as the representative of the deity. In this event it often became his private property, whose benefits he sometimes allowed the people as a privilege. During the time of the Reformation Hyde Park was used as a hunting ground by King Henry VIII.

Cunningham observes that to the passionate fondness of the early English sovereigns for the chase we owe in all probability the parks of London. With an increased desire to secure popularity an attempt to increase the natural beauties of the common led to the evolution of landscape gardening, which under the guidance of despotism assumed early the reverse of its present tendency, that nature unadorned is adorned the most.

Under Louis XIV. that most magnificently artificial of despots, the people were shown in the public gardens the private taste of their sovereign, as magnificently displayed through the striking but most artificial labors of Le Notre, one of the greatest, albeit mistaken landscape gardeners of that time.

With the quiet decay of absolute power, when Louis XIV. was checked by Marlborough, came a repugnance to artificiality. Of the battle between this naturalism and artificiality as applied to parks, Dumas furnishes an amusing yet instructive picture in a conversation between Louis XV. and Marie Antoinette.

During the reign of George II., Kensington gardens were almost private, as the public were only admitted on Saturdays, when the king and court were absent, and then only in dress costume and at a much later period there were restrictions in force giving the gardens something of a private nature. They are now free to the public.

The parks on the continent of Europe pursued the same evolution. Forests, hunting grounds, resorts of robbers and finally on the advent of the humanitarian impulses of the eighteenth century, parks dedicated to the people. The parks in manyGerman duchies, however, owed their existence to advertisement of the gaming places, from which the dukes drew their chief revenue, of which Monte Carlo is at present the best existing illustration. Under the first French republic, attempts at public parks were made in Paris. Under the second republic these attempts were renewed and extended. Napoleon III.

adopted these humanitarian theories and to him Paris owes its magnificent system of parks and boulevards which the third republic has increased and enhanced.

To discuss parks with the completeness the importance of the subject demands would require more than one evening, hence it will be impossible to dwell upon more than the most important salient points. Any one of the various departments of a park management would furnish ample material for an evening's discussion. I shall, therefore, mainly confine myself to the park we know best of all—Lincoln Park.

In the United States the park problem is more complicated than under an aristocracy. A park in the United States must present features that attract all grades of culture. The contrasts such as Victoria and Hyde parks of London present, would be as undesirable as they are, fortunately, impossible. Parks are what sanitarians have so often called them, lungs of the city, and during the summer they emphatically prove such to the multitude. In this sanitarian view, both the recreation feature and the source of mental training which parks present are united. To the denizens of the slums the park furnishes fresh air, both to mind and body. The sordid, filthy atmosphere is replaced by one intellectually and morally stimulating. The park is of even more value as a preventive of physical and moral evil than directly as a preservative of physical and moral health.

The land best fitted for park purposes is as a rule least suited for agriculture, because of irregularities of surface, profusion of rocks and ravines and forest trees. This fact has rendered the Chicago park problem a difficult one to the landscape gardener, because of the lack of natural aids. Even that boasted triumph of the Paris landscape gardener, the Buttes Chaumont, had, although a gypsum quarry worked for ages, many irregularities of the surface which lent themselves to the park design. In Chicago all the seemingly natural vistas are the products of studied labor. The results of this expenditure of money, time and skill by Chicago's public-spirited citizens are appreciated at home and abroad.

In the treatment of the grounds I shall confine myself closely to the conditions found in Lincoln Park. The founders of Lincoln Park were confronted by the problem of beautifying an arid, sandy waste, partly a cemetery, at the least possible expenditure. The results of their labors and those of their successors may be somewhat surmised from the following statistics:

The park, exclusive of boulevards, contains 310 acres.

There are ten miles of drives, or about 55 acres.

There are 19 miles of walks, 21 acres.

There are in lakes about 20 acres.

There are in lagoon 19 acres.

There are in lawns and building sites 195 acres.

There are about 25 miles of water pipe of all sizes.

There are about 90,000 lineal feet of electric cable conduit.

Trees were planted in abundance, but enforced parsimony in clay soil has proven an expensive economy. The mistake, made necessary by lack of funds, was committed of not properly so surfacing with clay soil as to produce lawns capable of withstanding summer heat. The desire of the American for hasty results cannot be satisfied when it is a question of park improvements. Thorough work cannot be done hastily, and permanency in trees and lawns can only be secured by it. If, as in Lincoln Park, the surface be sand, a clay subsoil must be made, and over it a black loam should be spread. In this should be sown red top and blue grass seed in equal proportions. Should a green sward be required in shorter time, to this should be added a small proportion of white clover. Before sowing, too much pains cannot be taken to render the lawn surface smooth and even three or four bushels of grass seed to the acre will be needed to speedily produce a handsome turf. If this be done in the early spring, a good lawn-like surface will be secured by midsummer. The next season will see a fine, close turf. Thereafter the beauty of a lawn will depend on frequent mowing. More than two weeks' growth will produce bristly stubble after mowing in place of a soft, velvety surface.

The lawn should have a top dressing every two or three years if the soil be rich, or every season if it be poor. During the winter when the ground is frozen is the best time to apply such a top dressing, which may be a compost of any decayed vegetable or animal matter. Every season the lawn should be examined, weeds taken out and bare places sprinkled with fresh seed. Wood ashes, either fresh or leached, or commercial fertilizers may be employed with success.

As the neatness of a well kept lawn depends mainly upon the manner in which it is mown, and as this can only be done properly where no inequalities in the ground exist, it follows that the surface should be kept as smooth as possible. In the spring, before the grass starts, the lawn should be examined and all holes and irregularities filled up. The occasional use of a heavy roller, after rain, will greatly tend to remedy defects of this nature.

Every park should have a complete system of water mains accurately recorded on a map, showing location of all connections and valves, and whether the latter be "right" or "left hand."

Walks and drives are a necessary, but not an ornamental feature of a park system. While the general lines should be direct, they may be in such gradual curves as appear easy and graceful without passing into formal stiffness. Care should be taken that the curves do not pass into serpentine lines, which are never followed by the public without protest. A road should never curve without real or apparent reason. The elevation of all walks and roadways should be such as to secure good drainage into sewers. Adoption of a plan for surface improvement should depend on the question of drainage, as a good sewage system is absolutely necessary to good roads, walks and lawns.

There is no subject of more importance to the horticulturist than

transplanting trees. The first and most important consideration in transplanting is the preservation of the roots. This does not refer to the larger and more important ones alone, but to the numerous small fibers and rootlets so necessary in assisting the tree to recover from the shock of removal.

Of course it is taken for granted that when the tree is transplanted, that the bed in which it is placed will be composed of the best possible soil to be obtained, and in sufficient quantity, as it is a fact that after the tree reaches the outside of the line of black soil in which it is transplanted, it will then cease to grow. That is, if it is placed in sand as we have in Lincoln Park.

The larger roots serve to retain the tree in position and carry the fluids or tree-food, but the small, fibrous roots imbibe food, and the destruction of these is dangerous in the highest degree to the health of the transplanted tree. To avoid this in a tree not nursery grown, a large enough area should be removed to include the majority of the small roots.

If the work be carefully done very little pruning will be necessary, and the risk will be comparatively small.

Next in importance to the successful task of transplanting is the question of the tree to be transplanted. These must be selected with a view to making a final harmonious effect, whether the trees be planted singly or in groups.

Form, foliage and color have to be considered to secure for all seasons the best effect and break the monotony of the scene.

Whether one kind of tree only should be used as borders has been the subject of much thought by park superintendents. The elm has usually been selected, not merely on account of its stately form, but also because of the prominence given it by tree growers who successfully transplant it after attaining considerable size. The oak is gradually growing in favor by those who plant for posterity, and makes a handsome border tree in time.

Every park should contain an arboretum, so that anyone who wishes may become acquainted with trees and shrubs that naturally flourish in the open air in the locality. Trees and shrubs should be labeled, giving both common and scientific names.

In Lincoln Park nearly all the walks are constructed of coal ash or cinders, and are in the end very expensive. They are dry and dusty during the summer season and muddy in winter. They receive constant sprinkling in dry weather, and are even then dusty and unpleasant under foot. After every rain storm repairs more or less extensive are necessary, to say nothing of removing the cinders from catch basins. During the past two years a small amount of walk has been constructed with a four (4) inch surface of finely screened Joliet bank gravel. This has proven so satisfactory that more will be built next year.

Why not construct permanent walks in Lincoln Park? There is no real objection other than that of expense to such an improvement, and the day is not far distant when good walks will be considered as necessary to a beautiful park as trees and lawn.

To prevent accidents to wheelmen it has been found necessary to remove the large clumps of shrubbery that formerly hid the view at sharp curves in the roadways, and emphasizes the advice to make roads of easy curves where lines are not straight.

The subject of pavements in general having been discussed before this society at the previous meeting, it is unnecessary to treat the subject at length.

As to construction of a park road, it does not differ materially from the construction of a roadway elsewhere. The main consideration is to decide upon the best kind of paving for parks, and this is, in my opinion, macadam or asphalt. I would advise a smaller crown than is usual in public street work. If macadam is selected the only change from ordinary construction to be considered is to cover the broken stone with crushed bank gravel and fine granite, instead of limestone. Too much stress cannot be given the subject of rolling, for if it be thoroughly and carefully done, the life of the pavement will be correspondingly lengthened.

All macadam roads require frequent sprinkling, and with care need not be made muddy where it was only desirable to lay the dust. Bicycle roads should be built in the same manner as roadways. The only difference is they require less depth of road metal.

In the construction of bridle paths care should be taken to secure proper drainage. Clay or heavy loam as a sub-base, covered with a light, sandy soil, gives a clean and pleasant path for equestrians.

In 1890 Central Park issued permits to 75,000 children. In Lincoln Park many more than that number each summer issue such permits to themselves. It is greatly to be desired that at an early date ground be set aside in Chicago or vicinity for a garden, where the beauties of the animal and vegetable kingdoms may be collected and in such form as to afford instruction and pleasure for all time to come.

The menagerie has long been an instrument of civic government. The chief demands of the Romans at their decadence was bread and circuses. To the last, so far as its zoological features are concerned, Lincoln Park has adhered in the natural course of evolution. It is not only park scenery in the midst of a city, it is a zoo, botanic garden and recreation grounds.

DISCUSSION.

Mr. T. T. Johnston: There are one or two points mentioned in the paper just read that I think are worthy of some notice perhaps. One of them is with reference to the propriety of making the park a play ground. If I understood the paper correctly, the writer thought it should not be made a play ground, that there should be no racing track for bicycles, no base ball grounds, no cricket grounds, no lawn tennis grounds, no place for the small boy to play on the grass, and things of that kind. It occurs to me that the park is the location both for pleasure and health, and the pleasure should not be confined to simply looking at the park, walking along the paths and seeing the flowers grow and looking at the grass and the

various signs stuck around, admonishing persons to keep off the grass.

I was coming to the city this evening on the Chicago & Alton R. R. We had arrived at the point just east of where the Alton crosses the south fork of the river. The air brakes were applied suddenly and the engineer commenced to toot his whistle, and as we passed along we could see people looking aghast in the direction the train was going and everybody on the train was excited at what appeared to be the situation outside, and as the train went on we passed a little urchin with a lump of coal in his hands about the size of his head, and looking back at the engine, not with a look of fear and terror, but with a look of intense indignation that he should be put to so much trouble on account of the passing of a train. That little fellow had picked up that coal, not perhaps so much because he needed it, but because he had the opportunity. And as I heard the paper, I could not help thinking how much better off that little fellow could have been tumbling around on the grass somewhere. If he had been in one city I know—in Washington—he would have had a place to play, because Washington is a city of parks and flowers, lots of grass and trees and lots of places where he would have found better amusement than playing on the railroad tracks, and I think if he had been there he would have had some inspiration to be in his after years a bigger and better man than perhaps he will be. The park is a place where one sees all that is nice in nature, perhaps the nicer elements of nature, broad lawns, spreading trees, and one gets fresh air and finds much that leads to good health, and in so far as the park can contribute to those things, I think it should. That city is the best provided with parks, which affords so much park area that there is no danger of hurting the grass. Where there is a great deal of room to move about, people can play base ball, or anything of that sort can be played that will keep the muscles moving, that will give exercise, and the parks go a long ways toward making all these things.

With regard to the element of health in a city, I have had some opportunity during the last six or eight years to look into the matter. We have data in the city of Chicago for studying that matter perhaps more closely than in any other city in the United States, perhaps anywhere, because the population is enumerated once every two years. Not over the whole city, but in fractional parts of the city, in little districts that contain perhaps generally about a thousand people. That enables one to study health statistics and the health of the population upon aggregations of small areas. The health records of the city record the deaths that take place, locating them in the exact district in which they occur. That gives data by which one can discover the number of deaths from any given disease upon any small area and correlate it to the number of people living on that area. That area may be a quarter of a square mile or a whole square mile, or, what is perhaps not so essential, a ward. In 1890, 1891 and 1892, in connection with the matters relating to the sanitary district of Chicago, I took a record of the deaths each

year in the different parts of the city and located them upon a map. That map contains the location and density of the population upon various small areas scattered about the city. In that data I had an opportunity to discover the death rate, perhaps on any quarter square mile in the city, or upon any half square mile, and it enabled me to correlate the death rate to the density of the population on any given area, say along such area as Clybourn avenue, Milwaukee avenue, along the lake shore or in Pullman, or upon the west side in the vicinity of Union Park, or upon areas in other parts of the city. That examination pertained to several classes of diseases which are accounted as preventable diseases. Typhoid fever was one class, diphtheria and scarlet fever was another class and intestinal diseases formed another class. The result of that examination was to show the death rate from those several classes of diseases upon small areas in different sections of the city and develop some matters of information that are worthy of note. For instance, it was found in cases of typhoid fever, the percentage in some sections was twenty times as great as in some other sections. The same was true in scarlet fever and diphtheria and also in intestinal diseases. That ratio may seem very large, but it was found to be true in several sections of the city, in several classes of diseases. In the cases of typhoid fever, the distribution of death rate seemed to be more dependent upon water supply than upon density of population, but in cases of scarlet fever and diphtheria and in cases of intestinal diseases, as cholera infantum, which disease is perhaps more prevalent with us than any other, the distribution of this disease was found to correspond with the density of population and with those parts of the city in which the worst atmospheric conditions might be expected.

Now it occurs to me that if the ratio of death rates varies from 20 to 1 in different parts of the city for those diseases, that perhaps the importance of parks in relation to this disease may be worthy of note, and the influence of those parks upon affecting those death rates may be worthy of consideration. If we had our parks more widely scattered through the city, if those parks were located where people could get to them and play in them and get fresh air, it might be a matter contributing very largely to our civic welfare. The death rates from the several classes of diseases might be said in general to become more intense as the region examined became more remote from the parks or became more remote from regions where people live in more segregated manner. Among the dense population on the North Side along Clybourn avenue, on the West Side along Milwaukee avenue and Blue Island avenue you will find the death rates more intense, and I dare say the people living in those localities frequent the parks less than any people living closer to the parks, and if in the center of those localities we could have parks as extensive as Lincoln Park, or Garfield Park, or South Park, the death rates from these special diseases would be very much less than they are.

I cannot help but believe in the light of the information that was

furnished by those examinations into the death rates, that the park influence is very valuable, and that it would increase in value as the opportunities for general use of the park were greater, so that every day the children and the grown folks might go into the parks and secure the advantages they furnish.

The Chair: Mr. Alexander, have you any remarks to make on Mr. Foster's paper?

Mr. Alexander: The only remark I would care to make is on the question of games. I did not understand Mr. Foster to take the position that Mr. Johnston understood. The way I understood was that Mr. Foster objected to racing tracks and semi-professional games in the park, not making objection to the use of parks for all classes of games, but wishing to keep the professional out of it. And I can see his reasons for that, for by retaining the grounds for the younger, for the boys and for the clerks who can probably get out only Saturday afternoon in the summer, I think the advantages would be more widely spread, and I believe as Mr. Johnston does, that a roll in the grass will do any boy good, and I think in that respect that the park systems in Chicago are far ahead of many of the parks in the east. In Lincoln Park the "Keep off the Grass" signs have practically disappeared and you will only find them on the newly made lawns, where grass has been freshly sown, all along the slopes from Grant monument north. It is impossible there to give the public free access to the slope on account of the light, sandy soil that has been used in the construction. On week days it is quite strictly adhered to, but on holidays and Sundays when the park is filled with people they are permitted to go wherever they choose.

The chair here read from Mr. Foster's paper what he had said regarding games, etc., in the parks.

Mr. Hill: I would like to repeat something that Mr. Maddock said last week; that is, that the conditions in the parks and boulevards are quite different from the conditions in the ordinary city streets. I think I can indorse nearly all that Mr. Foster said in his paper in regard to roads, as being applied to park roads and boulevards. For example, he speaks of the proper crown for the macadam road, which I think is correct under his conditions, but in a city street where streets are not taken care of, where they are not cleaned often, where they are not repaired frequently, it is necessary to give more crown. Now a good many people, as Mr. Maddock said at the last meeting, come to the park superintendents and engineers to get information in regard to street building and then they take the data they get there and try to apply the same to some country village or small town where the conditions are very different and the result is that a great many engineers build their roads, especially macadam roads, with the same comparatively flat crown that you find in the parks or boulevards. Now in the parks and boulevards the crown is sufficient because these drives are taken care of constantly, always kept clear and always repaired and there is no provision made for allowing the surface to wear down, because new material is added as soon as it is worn out. Therefore, the advice

that these engineers give is not good advice for the purpose for which you wish it.

Another point that Mr. Foster speaks of is concrete gutters. I know in some cases that people advise against concrete gutters, but where the roads are well taken care of, the gutters are kept clean, and with a uniform pavement from one curb to the other, I think they look better than if you have a different kind of gutter. But you take an ordinary city street, and gutters not taken care of and the horses pawing them makes the gutters irregular, the result is that the water does not run off, it stays in places and causes the street to wear out.

Mr. Maddock: There is one point touched on by Mr. Alexander about which I would like to get some information. He referred to the planting of trees in the parks. I live in a town where most of our shade trees are soft maple and elm and every two years we are bothered with insects. This spring a gentleman suggested to me that he thought the remedy lay in having a large variety of trees similar to those in the parks. His reason was that where there is a variety of trees there is an insect which takes to each tree, and that the insects, instead of destroying the trees, those peculiar to the oak for instance, would destroy the insects peculiar to the maple. Now I do not know whether this idea is correct or not. I thought perhaps some gentleman here might know something about it.

Mr. Maher: I was impressed with the one thing Mr. Foster brought out. I think engineers ought to thoroughly bear in mind themselves the difficulty of rolling macadam. I know people interested in city streets have an idea that when a street is finished it ought to be everything the law requires and be finished for all time. Of course, as has been stated, in the city we have not money to spend on repairs of the streets as they have in the parks, but Mr. Foster brings out the fact that, while it is absolutely necessary that a macadam street be thoroughly rolled from the bottom to the top, it is not by any means finished. The rolling just serves to compact the material and the street is really built by the traffic upon it. And that is one reason why I think macadam has not been very popular in the city, because it is not finished when the contractor gets through with it by any means, but it requires constant attention after that. That is one thing that the general public does not seem to know, and many an engineer has been blamed for months after a street is finished. If they will only wait till the traffic goes over the street, it makes an immense difference within a year or two.

The Chair: It seems to me there is one interesting point in Mr. Foster's paper. That is in regard to draining the land by brick sewers and tiling. If any gentleman here is familiar with the subject, it might be interesting to discuss. That is, supposing there is a brick sewer laid, we will say ten feet, what area is that supposed to drain? Mr. Foster makes the general statement that it makes the land very dry and kills the trees. How far away?

Mr. Alexander: There is one thing that I would like to mention, and that is the effect of roots of trees on sewers, and I would advise

engineers by all means to fight against the use of willow trees anywhere in the vicinity of sewers. In 1894 we took up a nine inch sewer from Webster to Fullerton avenue that was entirely filled with roots, so much so that it was impossible to clean them out, without taking up piece by piece and removing it, and they retained their shape after being pulled out of the pieces of pipe. I know that the roots of the willow tree will go through brick sewers. Of course, in this tile sewer you would not expect to see the same results, but the fact remains; it did go through and fill the sewer.

The Chair: Then the sewer did not kill the willow tree?

Mr. Alexander: No, it killed the sewer.

Mr. Davies: I have heard a great deal about sewers being filled up with roots, and especially willows, but I never came across any in my own practice. Speaking of brick sewers draining the surrounding land, I have known cases where wells some half a block away from the street have been drained dry in that way. Of course they were shallow wells.

Mr. Johnston: There is one point that I thought of a while ago with reference to the parks in Chicago that might be worth speaking of in this connection. The West park board, I believe, provided a bathing tank in one of their parks during the past year, I think something on the plan instituted in Lincoln park. The one in the West park, I have forgotten which park, was rather small, so that on one occasion it was said that the bathers looked like a nest of snakes in an Arkansas swamp. The bathing tank perhaps should have been larger. It occurs to me in that connection that if such a thing is desirable, it might be made on a larger and perhaps more extensive scale than was attempted at the West park. We all know that there is an abundance of artesian well water under Chicago, some of which is reached at a depth of 2,000 feet. The temperature of the fresh water reaches about 80 degrees; that of the salt water may be higher. I know that at Waco, Texas, where water is taken from a depth of 2,200 feet, the temperature is about 104 degrees. Why would it not be a desirable feature in some one or more parks to construct a bathing basin with perhaps one or two acres area and filled with water from an artesian well? An artesian well could be made to yield water enough to keep such a basin fresh and warm at all times. One of the obstacles to bathing about Chicago, as I understand it, has been the cool temperature of the water, especially in the lake, but if ample bathing basins could be provided in the parks or inland that would maintain water at a desirable temperature, it occurs to me that there would be more bathing done than there is. I would like to hear from some of the park people on that point.

Mr. Schrader: The natatorium at Douglas park, at Ogden avenue, has proved quite popular, at the present time at least. I think some days there have been 4,000 visitors there. It is constructed with two tanks, a smaller one for the ladies, which is 55 by 60, and the larger one for the gentlemen is 55 by 120. It is entirely in the open except for the dressing rooms, which are surrounded upon four sides. I think we have departed from the usual rules of the parks

in putting in the natatorium, as well as the racing track, which I believe Mr. Foster also objects to. The track was designed chiefly for fast runing. It was also thought it would take away a great deal of racing from the boulevards, which is dangerous, although they are still asking for the use of the boulevards for racing.

Mr. Alexander: I would say in reference to bathing that Lincoln park last year attempted to take care of the public, but it was simply a trial. The commissioners this year had intended to make more extensive preparation and be able to accommodate possibly several hundred at a time. We had a bathing beach for boys and girls under 14 years of age, and most any day in the summer you would find several thousand—and that is not figuring one too many—in the water at one time. But, owing to the bathing place tried last year being close to the sanitarium, it disturbed the people who went there with sick babies too much, and it was taken down this spring, and, other improvements being thought more necessary, they delayed their plans until next year.

In regard to artesian wells, we find that it is pretty difficult to get artesian water for drinking purposes in Lincoln park, and it is found necessary to attempt to clean out and deepen those wells. The south one we have not been able to pump water from for a couple of weeks, and we now have a contract for cleaning that well. If successful, we will try the other. The water is about twenty-six feet below the surface of the ground, some eight or ten feet lower than it was a year ago.

Mr. Johnston: How deep is that well?

Mr. Alexander: About 1,650 feet.

Mr. Johnston: They have not driven any well down as far as the salt water?

Mr. Alexander: The well at the Lehmann estate is down about 2,100 feet.

Mr. Johnston: Do you know how near to the surface the water of that well rises?

Mr. Alexander: I have forgotten. I do not think it is a flowing well now, but I think it has been. There are quite a number in that vicinity on the North side, put down by the breweries. This artesian water is fresh water.

Mr. Johnston: It occurs to me, by going into the salt water, even if it costs quite a little to get it out of the ground, it would be nice to take a sea bath right here in Chicago; to have it on a sufficiently large scale so there would be room enough to dabble in it without causing anybody inconvenience, and covering three or four or five acres. It would be more popular than a small basin. If the small basin they have constructed has proved so popular, it would be all the more so with more advantageous arrangements. I just simply offer that as a suggestion.

Mr. Bley: I would like to inquire, speaking of seeking for salt water for bathing purposes, whether Mr. Johnston means to imply that Chicagoans are too fresh as a rule?

Mr. Johnston: I will answer for one, that I'm pretty fresh.

The Chairman: There have been no remarks made regarding the monuments in the parks or the public buildings. Now there is quite a question regarding the location of public buildings in the parks, and the artistic features of the bridges and their construction might be touched on. Has any one anything to say on these points?

Mr. Schrader: It is the policy of the South park board not to have any monuments of any kind. At least it used to be.

The Chair: They have public buildings there since the World's Fair.

Mr. Kellogg: There is another phase that has not been set out, and that is the military phase of the park system of a large city. That is not so much necessary in the United States as it was in Europe. When Louis Napoleon advocated parks, he took very good care at the same time to introduce the military part of it. The parks in Europe, for instance in Bremen, or in Hamburg, or in Cologne, are made from the space that was occupied by the old ramparts. They are now mostly flower gardens in a long strip, something like we have in Grand boulevard here. The park system over there is somewhat different from what it is here. There is no space in them, that is, in the ordinary park made since 1870, when it was proved that the fortifications of a city should be some eight or ten miles away. I have not examined the idea of their wheeling on the new wheel that we have, the bicycle, but I guess our parks are given over more now to the recreation of the people in different exercises than they are in Europe. In that comparison I just wanted to mention the military idea. When it was proved in 1870 that large guns needed to be defended at some distance away from the city, these old ramparts were taken down and parks created.

Mr. Schrader: I would like to ask Mr. Johnston at what probable depth we might here expect to find water at such temperature that it would be suitable for bathing?

Mr. Johnston: I think the water should be secured at any depth below 1,500 feet, if we excluded the top water, which I believe has not been done in any well around Chicago. At Waco, Texas, the water is not reached until you get down 2,200 feet and the temperature is 104 degrees, which is just about as high as a person wants to get into. They have a number of bathing establishments and sanitariums, relying on the temperature of the water for their patronage. I think there would be no trouble in getting warm water from the strata under Chicago below 1,500 feet. At Riverside there is a well about 2,000 feet deep, in which the temperature of the water is about 80 degrees. Water is received at all depths. If the water 700 or 800 feet from the surface could be excluded, I expect the temperature would be higher. At 2,000 feet it might be 100 degrees.

Mr. Alexander: I was told by the man who dug the south well at Lincoln park that the surface water was excluded. I do not know how perfectly, but the temperature of the water I should say was about 60. Both wells are about the same depth. All I know about the wells is what I have been told by the contractors, and in both cases it is said to have been excluded, and no iron tubing used.

XVI.

STEEL FOR BOILERS AND FIRE BOXES.

By T. L. Condron, Mem. W. S. E.

Read October 7, 1896.

The material for this paper has been collected from the motive power departments of several railroads, a few of the locomotive works and steel manufacturers. About fifty replies have been received by the writer to a circular letter sent to the chiefs of the motive power departments of the railroads, locomotive builders and steel makers, and the writer wishes to acknowledge the very great courtesy shown him by these gentlemen, not a few of whom went to the pains of sending, at no little trouble to themselves, long letters full of valuable information about the subject in hand. So far as possible the experiences given in these letters are brought together in condensed form under appropriate headings in this paper for ready reference by all interested, and it is hoped that further points may be brought up in the discussion.

FIRE-BOX STEEL.

Upon the diagram Fig. 1, Plate VI, there have been plotted those requirements in 32 specifications which can be expressed in figures. This diagram shows at a glance how many of the roads have adopted the specifications recommended by the Master Mechanics' Association in 1894. Wherever a specification differs from the Master Mechanics' Association specification, the difference may be noticed by an off-set from the continuous bands and the exact limits are shown on these off-sets by figures. Some specifications permit an increase in tensile strength and reduction in elongations for thin plates, and this is indicated where proper by a small jog at the extreme left of the space given to that road.

The limits allowed by each specification are indicated by dark spaces. The dotted lines indicate what is desired in each case.

CHEMICAL REQUIREMENTS.

It seems hardly necessary to specify the limits for all the different elements entering into steel and at the same time make rigid physical requirements. The writer is strongly in favor of limiting the amount of phosphorus and sulphur in the steel and likewise the amount of manganese, but believes that it is unnecessary for the buyer to go further than this. Excesses of these three elements tend to make the steel unreliable. Steel high in phosphorus may give a satisfactory test but surface inspection will discover numerous pits and scales on the plates, and while some plates may look smooth the inequalities of the steel will develop in service. The same is true of sulphur and manganese in differing degrees.

Several correspondents have spoken of plates failing in service, which plates when analyzed were found to be high in either phosphorus or sulphur or both.

The limits of phosphorus and sulphur should not exceed .03 per cent. in each case. The limit of .35 per cent. to .50 per cent. for manganese adopted by the Illinois Steel Company is good.

TENSILE STRENGTH.

It is at once seen that several roads have not adopted the high tensile strength specified by the Master Mechanics' Association, while the specifications adopted by the Association of American Steel Manufacturers is in marked contrast to the latter. Several roads write that they have decided to use only certain makes of steel for fire-boxes and prefer to specify simply the best product of these makers and not attempt to get the benefit of buying in the open market upon rigid specifications of their own. In every case the makers spoken of in these letters are members of the Association of American Steel Manufacturers and naturally it may be inferred that these makers adhere to the specifications of their association.

The Carnegie Steel Company, Ltd., writes that it has been their experience that a steel of less than 62,000 pounds tensile strength has been the most satisfactory to their customers, and adds that this

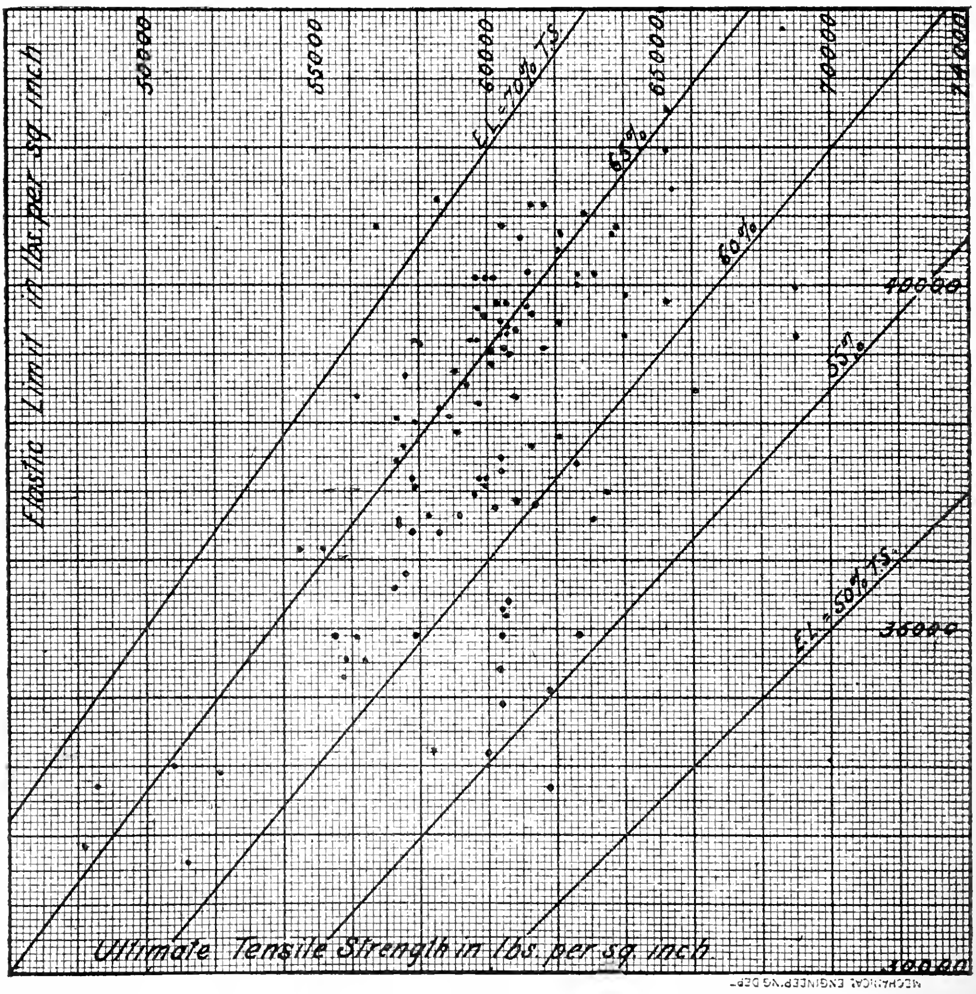


FIG. 149.

statement is based upon the record of their Claims Department. The Illinois Steel Co. recommend an upper limit of 60,000 lbs. for fire-box plates.

The specifications of the Association of American Steel Manufacturers were adopted, after a very full discussion of the subject by all of the plate manufacturers of the country, and while a few preferred to have a range of 50,000 to 58,000 lbs., the opinion of the majority favored the 52,000 to 62,000 lbs. range for fire-box steel.

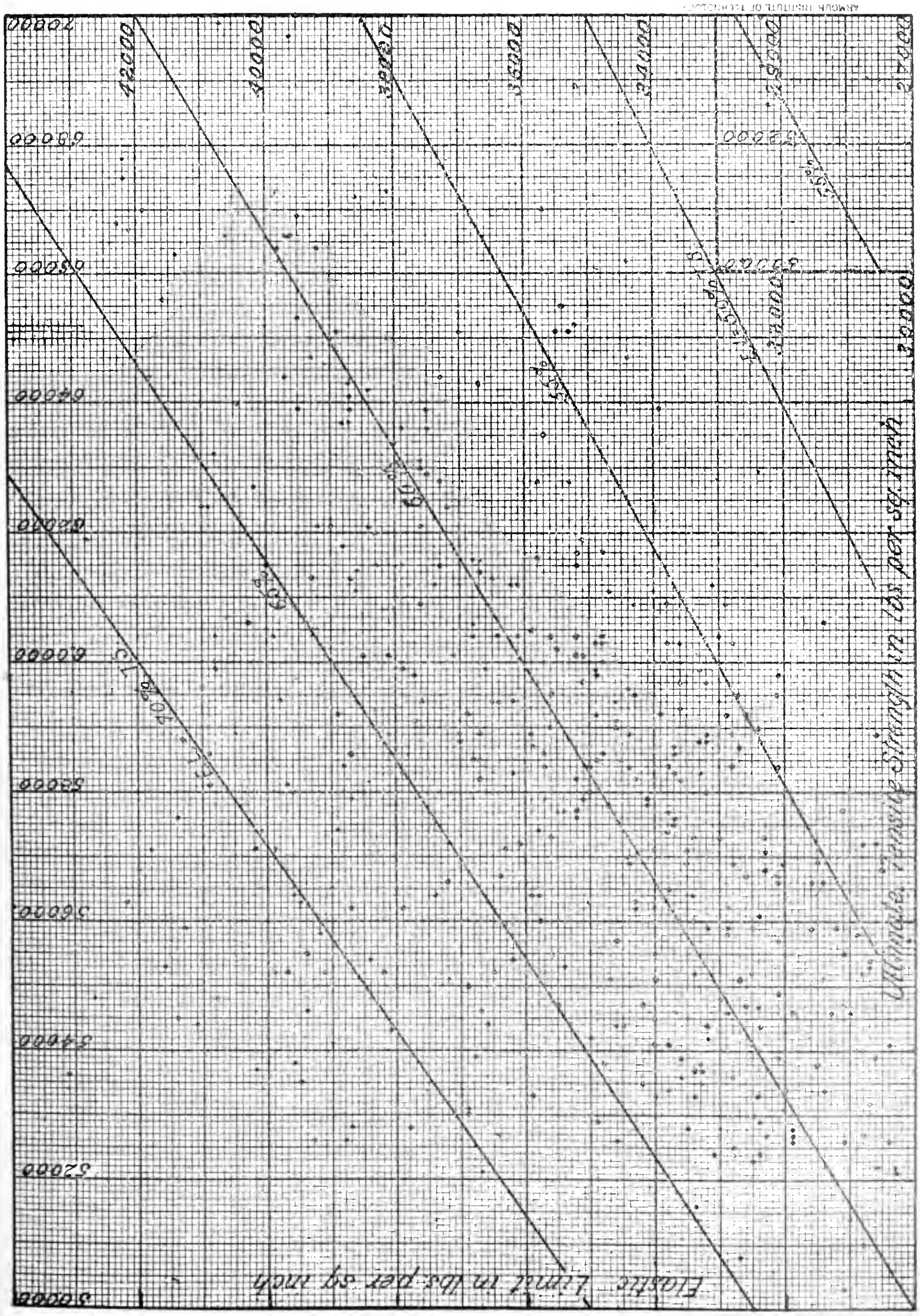


FIG. 150.

This shows that experience has led the steel makers to recommend very soft steel for this use.

In the same connection this statement is received from the Union Pacific road:

"Until three years ago we allowed a limit of 65,000 lbs. in the tensile strength. For two and one-half years our experience with steel of from 50,000 to 56,000 lbs. tensile strength leads us to believe that it is better material than that of a higher tensile strength, as it is less liable to crack."

From the New York, Chicago & St. Louis Railroad comes the report that they specified a tensile strength, desired, of 56,000 lbs. for 12 new boilers and fire-boxes built in 1895. And an elongation of 26 per cent. and reduction of area of 60 per cent., which they feel insures a good ductile steel.

The statement of one correspondent, that "what is most necessary to guard against in plates and stay bolts is cheap material which is on the market, and the following of specifications of parties not familiar with actual manufacture," has a great deal of wisdom in it.

Although the Illinois Steel Company is a member of the Association of American Steel Manufacturers, their specifications for firebox steel are noteworthy in that they place the ultimate strength at from 50,000 to 60,000 lbs. and differ from the association in chemical requirements as indicated.

ELASTIC LIMIT.

It is noticeable that the specifications all omit any reference to this property of the steel and experience goes to show that it is quite as well to do so, as the "elastic limit" is such an indefinite point when determined in the ordinary way that it is a poor operator indeed that fails to secure on a testing machine the elastic limit above one-half of the ultimate strength.

Figs. 149 and 150 are interesting as showing the wide variation in the elastic limits. Fig. 149 represents 100 tests made at the Homestead mill of the Carnegie Steel Company, Ltd., and Fig. 150 about 400 tests made at the South Chicago mill of the Illinois Steel Company. The first lot of tests were made on a machine having the counterpoise controlled by a hand wheel. The second lot on a machine on which the counterpoise is operated automatically. In the first case there is a decided personal equation of the operator keeping his scale beam balanced, which affects the determination of the "elastic limit," and usually this is recorded two to five thousand points too much. In the second case the only personal equation is in selecting the point to record as the elastic limit. As the stress approaches the elastic limit of the specimen the scale beam generally drops and rises again several times instead of only once. The Figs. 149 and 150 seem to show how little value can be attached to the "elastic limit" as determined in commercial testing.

REDUCTION OF AREA.

The writer is inclined to believe that there is no great need for this being noted in addition to the elongation. It is true that it adds but little trouble in recording the test, as it does not necessitate an extra setting of the slide rule.

ELONGATION.

While the Association of American Steel Manufacturers specify a minimum elongation of 26 per cent. in 8 inches the Master Mechanics' Association specifications and those of nine railroads drop this to 22 per cent. and one company even lowers it to 20 per cent. This surely is not wise. What is needed for fire-boxes is a ductile steel, and an elongation of 24 per cent. is certainly none too low. The $\frac{1,450,000}{\text{T. S.}}$ of the Pennsylvania Railroad is equivalent to 26.4 per cent. for 55,000 lbs. T. S. and 22.3 per cent. for 65,000 lbs. T. S. There is good logic in this sliding scale but it is cumbersome.

BENDING TESTS.

Too much stress cannot be laid upon the importance of making hot and cold and quench bending tests upon steel for boilers and fire-boxes. These tests are easily made and unquestionably they are as important as the more elaborate tensile tests.

TRANSVERSE TESTS.

Where it is desired to get the very best plates possible it should be required that test specimens be cut both lengthwise and crosswise of the plate for bending. Often it is found that plates which will show a good test in the direction of rolling will fail completely in a transverse test. Indeed, it would seem best to have all tests cut transverse to the direction of rolling, as in case a defective ingot was used the transverse tests would show the fact more certainly, and the steel is always weakest in this direction.

There is always a marked difference in the tests taken from the two extreme ends of a long plate. This difference is frequently as much as three or four thousand pounds in the tensile strength. While the test from one end would pass the plate, the test from the other end would not.

The homogeneity test given in the following specifications is also a very excellent one and should always be made for both boiler shell and fire-box plates.

BOILER SHELL STEEL.

Fig. 2, Plate VI, shows a comparison of specifications for boiler shell steel in a similar manner to the comparison of fire-box steel in Fig. 1, Plate VI. In this figure the light bands across the diagram represent the requirements of the specification adopted by the Association of American Steel Manufacturers.

THIN PLATES.

It seems a mistake to admit thin plates of higher tensile strength and lower elongation than is required for thicker plates. Of course this is necessary if rigid chemical requirements are made, but it is more reasonable to require that thin plates shall be more, rather than less, ductile than thick ones, for the tendency to crack from a rivet hole is greater in a thin plate than in a thick one.

IRON VS. STEEL FOR FIRE-BOXES AND BOILERS.

The very general consensus of opinion favors steel rather than iron plates, even if it were possible to get iron of uniformly high grade. The Chicago, Burlington & Quincy Railroad tried "sligo iron" fire-boxes in the '70's with poor results, and this seems to be the experience of a large number of roads. The New York, Ontario & Western Railway has in service now a locomotive built by the Baldwin Locomotive Works in 1872 with 16 inch x 24 inch cylinders and 63 inch driving wheels which still has its original fire-box of "Bay State steel" and this box is apparently in as good shape now as ever. This engine is still running in the regular passenger train service.

BOILER FLUES.

A prominent boiler maker gives the following statements regarding charcoal iron:

"There is no question as to the relative wearing qualities of iron and steel with regard to corrosion, the advantage being in favor of the iron. Charcoal iron flues are better than steel flues for certain waters. On the other hand, it is very hard to secure a pure charcoal iron flue at the present time, and a first-class open-hearth steel flue is even better than the very best charcoal iron in many instances.

He further states that he has on file a letter from one of the highest priced tube manufacturers stating that the so-called "charcoal iron tubes" which they make are not charcoal iron at all, and if such a thing is wanted their customer must wait while they run through a special order at an increase of 40 per cent. in the price. This leads our correspondent to believe that a good quality of steel is to be preferred to any of the so-called charcoal iron tubes on the market, since the latter are not made in sufficient quantities to insure good quality of material.

The writer hopes that something valuable will be brought out regarding tubes in the discussion of this paper.

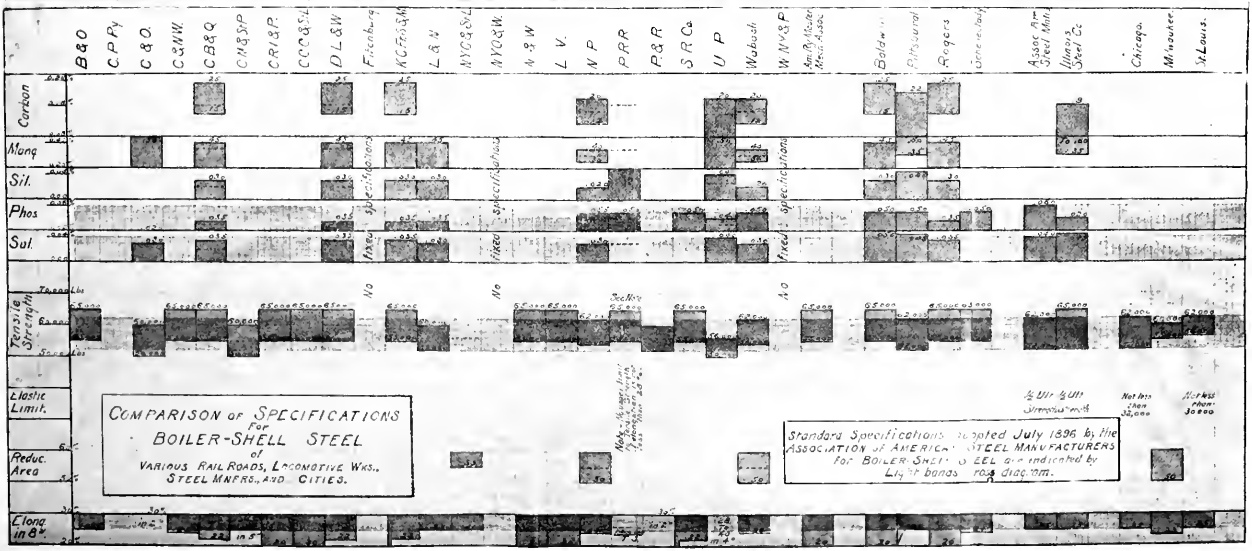
STAY-BOLTS AND RIVETS.

Iron is unquestionably to be preferred for stay-bolts and rivets, but this paper is intended to treat of plates only.

SPECIFICATIONS.

In conclusion I would present for your consideration portions of the specifications of the Master Mechanics' Association, 1894, and the Illinois Steel Company, November, 1895, which could not be included in the diagrams already given.


Comparison of Specifications for Fire-Box Steel of Various Rail Roads, Locomotive Wks., and Steel Manufacturers.
Specifications for Fire-Box Steel adopted by Master Mechanics Assoc'n., June 1894, are shown on extreme right one by Light bands across diagram.
Carbon
Mang.
Sil.
Phos.
Sul.
Tensile Strength.
Elastic Limit
Reduc. Area
Elong. in 8"


Comparison of Specifications for Boiler-Shell Steel of Various Rail Roads, Locomotive Wks., Steel Mnfrs., and Cities.
Standard Specifications adopted July 1896 by the Association of American Steel Manufacturers for Boiler-Shell Steel are indicated by Light bands across diagram.
B&O
C P Ry
C & O
C & N W
C B & Q
C M & St P
C R I & P
C C C & St L
D L & W
Fitchburg
K C F S & M
L & N
N Y C & St L
N Y O & W
N & W
L V
N P
P R R
P & R
S R Co
U P
Wabash
W N Y & P
Am Ry Master Mech Assoc
Baldwin
Pittsburgh
Rogers
Schenectady
Assoc Am Steel Mnfrs
Illinois Steel Co
Chicago
Milwaukee
St. Louis
Carbon
Mang.
Sil.
Phos.
Sul.
Tensile Strength
Elastic Limit
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SPECIFICATIONS

OF THE

American Railway Master Mechanics' Association

FOR BOILER AND FIRE-BOX STEEL.

ADOPTED, JUNE, 1894.

TEST PIECES.

"Test pieces, one from each plate, shall be in rough 2 inches wide and 36 inches long, and as nearly straight and free from twist as possible, and in no case must be annealed. Each plate shall bear maker's name, either rolled or stamped. The heat number and in addition such identification marks as may be specified shall be put on each plate and test piece.

When inspectors are present at mills, butt strips may be cut from any plate, provided such sheets are represented by test coupons. Where inspectors are not at mills, they must as far as possible be cut from a single sheet as rolled, and each sheet cut into butt strips will be represented by a test strip. All butt strips as well as test strips shall bear the heat number.

SHEAR MARKS.

Each sheet shall be accompanied by test coupon 2 inches by 36 inches long, attached at one end to sheet. To facilitate future matching, should it be necessary, both sheet and coupon shall be stamped twice across the division line with a shear mark, either round, oval, or of other agreed form; which mark should not be less than three inches across.

In cases where one large plate is cut into several smaller ones, all represented by one test piece, the same shear mark shall be stamped across each division line in two places before shearing, so that subsequent identification may be readily performed.

GAGE.

Plates measuring one-one hundredth of an inch less in thinnest part than that ordered, and all plates which show seams or cracks at the sheared edges, or which have cracks, slivers or depressions in the surface, or which develop defects in working, will be rejected. Rejection on account of thinness is to be made only after measurement of the actual sheet. Test pieces being prepared from the edge of sheets are liable to be thinner than the main sheet.

Test pieces when finished will be $1\frac{1}{2}$ inches wide in test section, and of full thickness of plate, and may be either parallel sided or of reduced section, and prepared either by longitudinal planing or

milling. Where reduced section is adopted, the distance between bottom of fillets shall not be less than 9 inches, and radius of fillets shall be not less than ½-inch and preferably more. Elongation will be measured between tram punch marks originally 8 inches apart, and on reduced sections placed approximately equidistant between fillets. In parallel sided sections, the tram punch may be applied at more than one point to insure breakage occurring between the marks.

SPECIAL REQUIREMENTS FOR SHELL STEEL.

Test piece having rough edges removed by filing, grinding or machining, shall, without annealing, bend over on itself, both while cold and after being heated to a cherry red, and dipped in water at 80 degrees Fahrenheit, without showing cracks or flaws on outside edge.

No chemical requirements.

SPECIAL REQUIREMENTS FOR FIRE-BOX STEEL.*

Homogeneity test is made in the following manner:

A portion of the broken test piece is nicked with chisel on opposite sides alternately, nicks being about one inch apart. Test piece is then firmly held in vise and broken by a number of light blows, bending being away from the nicks.

Laminations more than ¼ of an inch long to condemn.

The object of this is to open and reveal seams, due to failure to weld up, or to foreign interposed matter, or cavities due to bubbles in the ingots."

*The hot and cold bending tests should be required for fire-box steel.
T. L. C.

SPECIFICATIONS

OF THE

ILLINOIS STEEL COMPANY

FOR STEEL PLATES.

ADOPTED, NOVEMBER, 1895.

All tests to be pulled in an original section of eight inches with an original area of not less than one-half of a square inch. Test pieces to be carefully fitted up, having parallel sides with edges draw-filled. At least two tests should be taken from each ingot; one for tension, one for bending.

CHEMICAL REQUIREMENTS.

QUALITY.	CARBON.	MANGANESE.	SULPHUR.	PHOSPHORUS.
Fire-box	.16	.35 to .50	Not over .040	Not over .020
Boiler..........	.18	.35 to .60	" " .045	" " .040
Flange..........	.18	.35 to .60	" " .045	" " .040
Ship............	.15	.35 to .65	" " .060	" " .080
Tank...........	.10	.40	" " .100	" " .120

PHYSICAL REQUIREMENTS.

QUALITY.	ULT. ST'N'TH.	ELASTIC LIMIT.	ELONGATION.	BEND TEST.	QUENCH TEST.	HOMOGENEITY TEST.
Fire-box.	50,000 to 60,000	——	Not less than 26 per cent.	All tests must stand cold bending double and flattened down upon itself without cracking.	——	Nick the test about 1-16 inch deep; the first nick should be about two inches from the end; the second, one inch and a half from it on the opposite side; the third, one inch and a half from the second and on the same side as the first, no fracture to show a seam longer than ¼ of an inch.
Boiler.	52,000 to 65,000	Not less than ½ ultimate strength.	Not less than 25 per cent.	All tests up to ½ inch thick must stand cold bending double and flattened down upon itself without cracking, and over ½ inch must stand cold bending double over a curve whose inner rad. is equal to its thickness.	——	——
Flange.	52,000 to 65,000	Not less than ½ ultimate strength.	Not less than 25 per cent.		Tests must stand bending double after being heated to a cherry red and quenched in water at 80° Fahr.	——
Ship.	53,000 to 68,000	——	Not less than 22 per cent.	One test from each heat shall stand cold bending flat upon itself without cracking.	——	——
Tank.	Not over 72,000		Not less than 20 per cent.	Heat test shall stand cold bending over a curve whose inner radius is equal to its thickness.	——	——

REGULAR ALLOWANCE FOR OVERWEIGHTS.

THICKNESS OF PLATE—INCHES.		3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4 and over.
Width of plate.	72″ or under..per cent.	10	9	8	7	6	5	4½	4	3	3
	72″ to 90″....per cent.	....	11	9	8	7	6	5½	5	4	4
	90″ to 120″...per cent.	....	....	....	9	8	7	6	5½	5	4

SPECIAL ALLOWANCE FOR OVERWEIGHTS.

THICKNESS OF PLATE—INCHES.		$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$ and over.
Width	72″ or under..per cent.	16	14	13	11	10	9	$7\frac{1}{2}$	7	6	6
of	72″ to 90″....per cent.	....	16	14	13	11	10	$8\frac{1}{2}$	8	7	7
plate.	90″ to 120″...per cent.	....	....	....	15	13	11	10	$9\frac{1}{2}$	8	7

The above special overweights will be allowed, but IN NO CASE SHALL A PLATE BE MARKED OR BILLED ABOVE THE REGULAR ALLOWANCE FOR OVERWEIGHT. Three per cent. underweight will be allowed on fire-box and boiler, five per cent. on all other plates. Bessemer steel may be used in tank plates if not otherwise specified, but must be made to tank specifications.

AMOUNT TO BE CUT OFF TOP END OF INGOT.

QUALITY.	SIZE OF INGOT.—INCHES.							
	8x24	10x36	12x24	12x40	16x30	16x40	18x40	24x40
Fire-box......per cent.	20	22	23	23	25	25	26	.....
Boiler........per cent.	14	15	16	16	18	18	18	20
Flange........per cent.	14	15	16	16	18	18	18	20

Ample margin must be allowed on each side of plate to avoid lamination.

Special inspection must be given to all fire-box, boiler and flange plate, and every plate to be stamped by the final inspector's private stamp.

XVII.

TERMINAL YARDS.

BY H. G. HETZLER, Roadmaster C. B. & Q. R. R.

Read October 21, 1896.

A well known engineer and author makes the statement: "That terminal facilities, or the lack of them, have many times been an important factor in the success or failure of railways." This is undoubtedly true, as no portion of a railroad is of greater importance than its terminals in large commercial centers, as much of the business goes to and is received from them, and often the volume of business that can be handled over the road in a given time is governed by the amount that can be disposed of in the terminals.

It is therefore prudent that special attention be given to the arrangement of the terminals so that business can be handled with the least expense and delay possible.

The history of nearly all important railroad terminal yards tells us that at first they were composed of the main track, or tracks, and just enough side or yard tracks to meet the immediate demands. If the town or city in which the terminals started was not considered of note, little attention, if any, was usually given to procuring suitable property for yards, team tracks, freight houses, etc., to accommodate the business, which increases proportionately with the growth of the city; the impression being that property at no great sacrifice could be procured at any time, should it be needed. If, on the other hand, the city is an important one, property is valuable, and only such as is considered absolutely necessary is procured. In either of the above conditions it is practically impossible to design a plan to be followed in building the terminal yards to accommodate the business as it increases. The amount and kind of traffic to be handled is to quite an extent uncertain, and often the property which is procured is not located so that it can be used advantageously.

Yards are built many times by "piecemeal," starting in the first place with a track or two, to accommodate some unexpected increase in business. Other tracks are laid from time to time, as they are needed, no attention being paid to properly utilizing the property, the object being merely to get more track room for cars. This process is repeated until all of the available space is occupied by a conglomeration of tracks, no attention having been paid to their proper arrangement. This kind of a yard is expensive to operate. It is impossible to avoid delays, as the cars must necessarily be rehandled several times, whereas if the yard was properly arranged the amount of track laid would, perhaps, more than accommodate the average business, and the extra expense and delays be avoided.

It not infrequently happens that railroads have ample land, well

situated for additional yards, yet it is not utilized because the company does not appreciate the immense difference in cost between operating a yard that is well arranged and large enough to accommodate even the largest business, and a yard poorly arranged or too small to handle the average run of business. This can be better understood by considering the cost of operating a switch engine. Assuming $25 (a low figure) as the cost of operating a switch engine for one day, which includes the wages of the men, fuel, oil, etc., and also the interest on the capital invested in the engine, we find that the cost of operating a switch engine for one year, of 313 working days, is $7,825, which, capitalized at 5 per cent, amounts to $156,500. This figure gives an idea of what a railroad can afford to spend in building and rearranging yards so as to reduce the switching power—especially as the cost of one mile of yard track, when the grading is light, is not over five or six thousand dollars.

When it is found impossible to handle the business without great loss of time and expense, the engineer is called upon, perhaps for the first time in connection with yard work. His duties are to rearrange and practically rebuild the yard, and at the same time interfere with the handling of the traffic as little as possible. No definite rule or plan can be followed in arranging terminal yards, as the conditions and requirements are never the same in any two cases. The business to be handled differs, and the surrounding property conditions, which cannot be controlled—such as factories, and railway yards belonging to other companies—often render it impossible to make the most desirable arrangement. It is often advisable to procure property out of the thickly settled portion of the city, and turn over the property originally procured for yard purposes to local industries, team tracks, etc. It therefore devolves upon the engineer to meet these different conditions and obtain the best results possible.

It is at least certain that the importance of well arranged yards is often overlooked by railway managers, although from 25 to 33 per cent of the motive power of many railroads is used in switching service only. Instead of yards being looked upon as a collection of side tracks, as they frequently are, they should be considered, and in fact are, when well designed, a "machine" for sorting cars into different classifications. Such a "machine" should do its work thoroughly and without necessitating the expense of rehandling, or in other words, the continuous operation of a well designed yard may be compared with a manufacturing plant, where the raw material going in at one end, passes through the various stages and finally comes out the finished product at the other end.

As stated before, it is impossible to adopt a standard plan suitable for every yard, but when designing a yard, or when rearranging an old one, the following objects should be sought:

First. To design the yard so that the business can be handled at the least expense and delay possible, and second, so that the cost of maintenance will be reduced to the minimum. In order to attain the first result, the engineer should become thoroughly in

touch with the work in its details, acquainting himself with the amount and kind of business that is to be handled in the yard, and ascertain if possible, what the probable increase of traffic will be for a term of years. With this information at hand, the most desirable location with reference to other yards, local industries, etc., can be decided upon. Knowing the amount and probable increase in business, the amount of track room and the length of the different tracks best suited to handle the present business, and the space needed for tracks to accommodate the prospective business can be easily ascertained. The information pertaining to the kind of business will assist greatly in deciding upon the general plan for the yard that will be the best suited to take care of the various kinds of traffic.

As has been well said in an article written on this subject: "In designing a yard everything should be so arranged that cars will always move in the direction of their destination. No backward movement should be made if it can possibly be avoided. Every turn of the wheel backward causes loss." In addition to this all yards should be designed so as not to delay the movement of cars through them. To accomplish this, arrangements must be made for receiving and forwarding cars in the direction of their destination with the least amount of handling and so that any special kind of freight is accessible without necessitating the handling of other cars. To do this each yard should be designed so that every track is accessible from both ends, and cars can be taken away at one end while more are being put on at the other. Stub tracks should be used only when it is absolutely necessary, excepting when the track is comparatively a short one.

It is also necessary that all details pertaining to switches, switch stands, lead tracks, etc., receive careful attention, in order that they be located in the most desirable way. Switches should be placed as near together as practicable, so that the least amount of time will be consumed in going from one to the other, having the stands located on the side that will necessitate the least crossing and recrossing of tracks by employes. Yard tracks, when the conditions are favorable, should be straight and parallel with uniform centers. It is advisable to use ladder tracks at each end of the yard, of the sharpest angle that is practicable to operate. By so doing the property will be utilized to the best advantage and all switches will be near together and uniformly located with reference to each other.

Nothing assists more in the handling of cars in a busy yard than well arranged lead tracks. It is not at all uncommon to see too many tracks coming together into a single throat, thus preventing the working of more than one engine at a time on the track thus converging. The delay and expense incurred by this arrangement can be avoided by providing several independent leads. These leads should be so planned that no more work will be thrown onto them than can be handled by a single switch engine and so that they

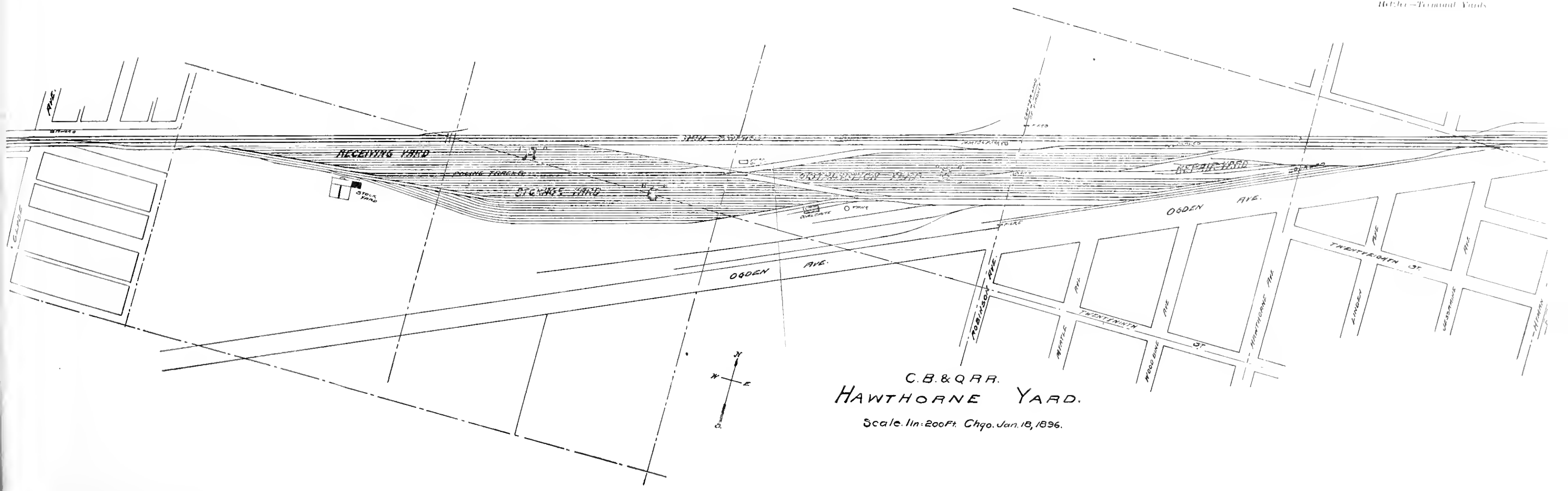
can be used without blocking other tracks. All lead tracks should, if possible, be straight, as it interferes greatly with the rapid handling of cars to have a lead track so out of line as to prevent the engineer from taking signals directly from the switchman who is coupling and uncoupling the cars. Lead and ladder tracks should not be nearer than from 16 to 18 feet center to center from other tracks. This amount of room is needed in order to make it safe for switchmen when throwing switches and giving signals. Standing tracks should be at least 12 foot centers.

After the plan of the proposed yard is completed and before any construction work has been done, the plan should be thoroughly gone over with the yard men who will be in charge of the business in the yard when built. While it may not be possible to exactly satisfy them, changes will probably be suggested which will assist in handling the work, and mistakes which would otherwise be overlooked are apt to be discovered, and the expense of remodeling later on avoided. It is no doubt true that the paramount object when building a yard should be to design it so as to properly meet the operating demands, regardless of the cost of maintenance. It is, however, possible to effect great savings in this particular, and still not materially change the arrangement.

After the plan of the proposed yard has been decided upon, and before any filling or track work has been done, a complete system of drain tile should be laid. One or more main sewers or drains should run through the entire length of the yard. Smaller pipes at nearly right angles to the main drains and emptying into them should be laid often enough so that catch basins can be located at points best suited to collect the surface water, and also near all switches, so that they can be kept thoroughly drained and from being frozen during the winter months. With a drainage system of this kind, the yard will be comparatively dry during rainy seasons, which not only assists in operating the yard on account of the good footing,but also keeps the tracks in much better condition and therefore less expensive to maintain. A standard frog for general use in yards should be adopted. By doing this, the number of extra frogs to be carried in stock, to use for renewals, will be comparatively small, and as they are made according to a standard plan, a worn out or broken one can be easily replaced with scarcely any delay to traffic. For the same reasons, standards should be adopted for switches, switch stands, and in fact for any article that is used to any considerable extent.

All complicated switches, such as slip switches, should not be used when it is possible to avoid them, excepting when interlocked or in charge of a switch tender, and then the center frogs should be movable point frogs. This is especially necessary when located so that all kinds of freight cars are drilled continuously over them, otherwise there will be a constant source of expense and delay caused by cars being derailed on the center frogs.

Rail that is nearly worn out can be used satisfactorily on tracks



C. B. & Q. R. R.
HAWTHORNE YARD.
Scale. 1 in: 200 Ft. Chgo. Jan. 18, 1896.

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intended mainly for standing cars on; there is, however, no economy in using it, as is often done, on track subject to constant use by engines and heavily loaded cars, such as important ladder and running tracks. On tracks of this kind it is economy to use either new second quality rails or rail equally good, for when in place they will remain in service for some time without being disturbed, which not only extends the life of the tie, as respiking is very detrimental, but also reduces the liability of accidents, and avoids the expense and delay to traffic caused by frequent renewals when badly worn rail is used.

The business handled in large terminals can be properly divided into two general classes, namely, passenger and freight business. It is not the intention in this paper to take up in detail the necessary arrangements for handling the passenger business. It is, however, important, especially if the passenger traffic is of considerable volume, to keep it separated as much as possible from the freight business. To accomplish this, special tracks must be provided to be used exclusively by this and other express business. These tracks should be located so as not to foul or come in contact with the freight tracks any more than is absolutely necessary; but if this does occur, the switches should be interlocked. Passenger tracks should be kept free from all facing point switches, excepting when they are protected by interlocking. This is especially necessary owing to the thickly settled territory and the liability of switches being tampered with.

The freight business of any important terminal naturally classifies itself into three groups or kinds of business; namely, in-bound business, out-bound business, and city or local business.

The in-bound business is made up of cars to be delivered as follows: To connecting railways, freight houses, team tracks, and private industries. The out-bound business is composed of cars received from connecting railways, freight houses, team tracks, and private industries. The local or city business is that which is received from connecting railways to be delivered to private industries, and from private industries for connecting railways. The business for these three groups should be received and forwarded to its destination with no more interference and delay than can be avoided. To accomplish this a suitable yard for each group must be provided and located conveniently for the traffic that is to be handled in it. Although the business to be cared for in the three yards is entirely different, yet they are all receiving yards and the demands made upon them are practically the same, or in other words, every main yard which is to be used for receiving and forwarding cars should be divided into three subdivisions, one being used as a receiving yard, another as a distributing yard from which all cars depart, and the third for cars that are held for disposition. This is well illustrated by the receiving yard at Hawthorne, on the C., B. & Q. R. R. I have a blue print of this yard here, Fig. 151, which shows the location of the yards referred to, with reference to each

other. The yard marked "A" on the print is the receiving yard. The one marked "B" is the distributing yard, from which all cars depart after being classified; and the one marked "C" is the "hold-for-order yard."

The relative size of these division yards depends entirely upon the character of the business. For example, if the bulk of the cars which are to be received are to be delivered to a number of different railroads and other concerns, and comparatively few are held subject to orders, the distributing yard must be large enough to provide a separate track for each classification, whereas the "hold-for-order" yard will be comparatively small. In receiving yards, cars are often switched by poling or staking engines on gravity tracks. This method is advantageous when the amount of business received for distribution and the number of classifications to be made is large enough to warrant the employment of the additional switchmen required. But when the number of classifications to be made is small, or the business light, experience has shown that it is not an economical method of switching cars. It is well to have all tracks in the "receiving yard" and "hold-for-order yard" of the same lengths and long enough to hold the average train. In the distributing yard this is not necessary, as it is often convenient to have tracks of varying lengths and assign the use of them according to the volume of traffic for each classification, making them in no case longer than convenience would dictate.

It is not necessary that the three principal main yards or groups—namely, those for handling the in-bound, out-bound, and city business—be centralized, or in close proximity, but if it is practicable to have them so located, it will appreciably lessen the cost of supervision.

The collection of yards comprising the freight terminals should be looked upon as one complete system and the same requirements concerning the movement of traffic applied to it as a whole, that are applied to each of the individual subdivisions.

DISCUSSION.

Mr. Randolph: I would like to ask Mr. Hetzler what is the standard frog in their yard?

Mr. Hetzler: The standard frogs used by the C., B. & Q. R. R. are Nos. 6, 7, 9, 11 and 15. The No. 7 frog is generally used in yards.

Mr. Evans: I am very much interested in the subject and very much pleased with the paper. I wish to say in regard to standard frog, that I think that in our work we struck a pretty good frog. It is such a length that with a 30-foot rail—the frog and the split switch rail made the "turnout"—we laid nothing except 30-foot rails, and a rail that matched the frog, so that any ordinary foreman could not go astray in his work, and it came out very nicely. It was a 9 degree frog, and our slip for that same angle. I think it has fitted

almost every case where we had occasion to build a yard in the last three or four years. It fits a 15 degree curve.

Mr. Randolph: Beginning sixteen years ago, for four years I devoted a great deal of time and study to the whole question of yard work. I was at that time connected with the Western Indiana system and laying out and building the yards to be used by the lessee companies, and at that time we used a great many No. 6 frogs in our yards and found them work very well indeed. When I came to Chicago to complete that work my practice had been almost altogether out in the country, where we had all out-doors to get around in, and the first thing I was ordered to do was to put a track in a salt dock down near Sixteenth street. I went down and looked over the ground and made some measurements, came back to the office and told the president it was impracticable, there was no room. He asked what was the best I could do. I told him a 24-degree curve. He said: "You go along and put it in." I put it in, and it operated right along. They have entirely remodeled those yards. I found at that time that leading into one of the elevators (the National) there was one track 106 feet radius, over which everything went into that elevator, and I have since laid a track (into the glucose works) on a radius of 140 feet.

Mr. Evans: I mention that angle because there was quite an opposition to it when we first used it, claiming that it was too sharp, and that the company could not use it, and there was great opposition to it by trainmen, and we were unfortunate in mentioning the degree of curve. If we had called it a 3 degree curve it would have been all right, but some one found out the curves were 15 degrees and that marked the yard, and the master mechanic actually reported that the engines were being torn to pieces. I am pleased to say that his statement was not founded on fact, and that we have been using this frog and degree of curve since then in the Western Avenue and other yards and got a good return, and we have been enabled to use property that was idle at the time. In one of these yards, though it was claimed that the land lay so it could not be used, we put in 16 miles of track, and it is a nice, complete yard in every way.

Mr. Randolph: That reminds me of an incident that happened in this same four years' experience. Before we had acquired certain property in this city we had to make a great many sharp curves; one was an 18 degree curve. In some way the engineers found out it was an 18 degree curve, and then they could not operate their trains, and I was ordered to go down there and correct the curve. I took a gang down there and had them put the 18 degree curve in another place, and never heard any more trouble from that quarter.

Prof. Whitney: I would like to ask if it is customary to make the gauge wider on these sharp curves.

Mr. Evans: Well, it has been three-quarter inch, and it really is necessary. The troublesome thing with a sharp curve is the spacing of the guard rail. That has to be properly done and it has to be maintained, or else you do have trouble, but good yard men are able to take care of that curvature in nice shape, and it is very fortunate

that they can do so in the city of Chicago, because the land in use for railroads was purchased in odd shape pieces and it is laid over, until with the different tracks they have it is all occupied.

Prof. Whitney: Is any portion of that Hawthorne yard operated as gravity yard?

Mr. Hetzler: Yes, these two tracks (indicating on plan) which are located between "A" and "C" yards, are gravity tracks. When the business warrants cars are taken from "A" and "C" yards and placed on the gravity track, and switched by means of a poling engine to the different tracks in the classification yard, which is marked "C" on the plan.

A Member: About what grade is used on gravity tracks?

Mr. Hetzler: I think that it is 20 feet to the mile.

A Member: I would like to ask what is the maximum length of tracks in Hawthorne yard.

Mr. Hetzler: When the yard was designed it was the intention that the tracks in "A" yard should hold 50 cars, but they will accommodate only 48 of such cars as we receive nowadays.

Mr. Reynolds: The cars are longer.

Mr. Hetzler: Yes, sir; the cars used now are considerably longer than they were when the yard was built.

The Chair: There is one thing in this connection which occurs to the chair, that you might get some expression of opinion concerning with some advantage perhaps to all of us with regard to the merits of such a system as has been proposed at the so-called Stickney tract. Has anyone anything they can tell us on that subject? There is a pretty big tract of land out there. We ought to be able to get some talk concerning it.

Mr. Randolph: There are forty miles of very fine track lying there idle, the best of its kind. I think the principle on which that is laid out is a correct one. It was alluded to in Mr. Hetzler's discussion of to-night, all the trains moving in the direction in which they ought to go. The object there was to keep everything moving in the direction for which it was intended. I have always regarded that as one of the most deserving projects which has been started in Chicago, and I cannot understand why the railroads would not take hold of it.

The Chair: Possibly they are waiting until after the election.

The Chair: Is there any further discussion of Mr. Hetzler's paper?

Mr. Sperry: I would like to ask what is considered the best form of switch stand for yard work? Some roads use a lever at right angles to the track and others other forms, and I would like to have some light on that subject.

Mr. Hetzler: On the C., B. & Q. in regular yard work we use what is known as the jack-knife stand. When the switch is located in a position where road engines and switch engines and different kinds of engines are constantly using it, we find that it is economical to use an automatic weight stand, so that if the switch is run through it will not be damaged. We have in use three or four different kinds of stands. I prefer a stand that throws parallel with the track. We have in use switch stands manufactured by the Ajax

Forge Company and Pennsylvania Steel Company, both giving good satisfaction.

Mr. Evans: I put that in the Wood street yard, and I think that was the man that owned the patent.

Mr. Randolph: I put that in the "Western Indiana yards."

Mr. Evans: They are very simple ,and I have thought them very satisfactory. We have them in both yards at Wood street, and they are very quickly handled and I think very satisfactorily. I believe that they ran a car in there one time that was very wide low down near the track, and a number of people claimed that the switch stands were wrong. I discovered that the car was wrong too, would not go past the guard rail on some of the bridges. I think that stand has been satisfactory. But we have used drop lever stands, and we use an automatic stand where we are likely to run through accidentally, saving the switch, but I question the advisability of using that sort of stand. I do not think men ought to be encouraged in their carelessness, but I think our operating men feel that they would sooner save their switches even if the men are careless.

Mr. Reynolds: I would like to ask Mr. Hetzler with regard to the position of that yard, that is, with regard to the city. What advantage is there for a yard to be located in the city? Would it not be cheaper for them to be outside?

Mr. Hetzler: Hawthorne yard is located seven and a half miles from the Union Depot.

Mr. Reynolds: Is it outside the belt line?

Mr. Hetzler: Yes, sir.

Mr. Reynolds: You consider it to be of greater advantage to be outside of the city than in the city, as some of them are?

Mr. Hetzler: Yes, sir, in some respects.

Mr. Sperry: I would be glad to hear if at any yards in the city they have taken up the question of operating switches on lead tracks by means of interlocking machines. I mean machines for working the switches without locking or without detector bar or facing point locks. It is a great saving of switchmen. A man at the central point can operate a dozen switches without running to and fro.

Mr. Hetzler: I do not think this method of handling switches has been used in any of the yards in Chicago.

Mr. Sperry: I was with the Pennsylvania road when we connected up switches by interlocking in the yard near Jersey City, and it proved a great saving in men.

Chief Engineer Brown, of the Pennsylvania Railroad, is opposed to using movable point frogs and slip switches. If you look at that Philadelphia yard, built within the last three years, you will find he has entirely avoided them.

Mr. Evans: I would like to ask what the objection to a slip switch properly used is. I do not mean to use it for main track trains, run at high speed, but the properly designed slip switch, it seems to me, is a great saving of space, but I find there is quite a protest against it within two years, and I have not been able to find out the reason for it.

Mr. Hetzler: Three or four years ago the C., B. & Q. had quite a number of slip switches in all of their important Chicago yards. When designing new yards or when making changes, the slip switch was very often used, as undoubtedly, as stated by Mr. Evans, it can be used advantageously when room is scarce. The slip switches were well designed and maintained, and yet they were a constant source of expense and delay, caused by cars being derailed upon them. This was especially true when they were located in tracks where all kinds of cars, in good and bad order, were constantly switched back and forth over them. Derailments were caused by the wheels climbing the unprotected point of the center frog and taking the wrong track. This was brought about to quite an extent by the rough handling to which cars are subjected when being switched, which often slues the wheel sideways when between the points of the middle frog, causing them to climb the point. And often cars with sharp flanged wheels and other imperfections, which would not be derailed on frogs properly protected, would be derailed on the middle frog of the slip switch. At first the C., B. & Q. used a No. 7 slip, but on account of the frequent derailments a No. 6 slip was used. Although the No. 6 slip was an improvement over the No. 7 slip, the distance between the unprotected frog being less, it has been satisfactorily proven to us that the slip switch is not a safe switch to use for short switching unless the middle frogs are movable point frogs, and when used, either protected by interlocking or in charge of a switch tender.

During the past two or three years the C., B. & Q. in Chicago has removed quite a number of slip switches. In fact this has been done whenever it is possible to do so and not interfere with the proper operation of the yard. When Hawthorne yard was first designed six slip switches were used, and now, as you can see from this plan, we have only one in use, which it would be impossible to remove without going to great expense.

Mr. Evans: We never use a slip switch unless we have a man to throw it, and our angle is practically the same as you use. There is very little of the center frog that is not guarded. We do not put one in where there is much switching over, except passage of trains in one direction. In that case I would consider it perfectly legitimate, especially to save space, and they do fit in very nicely very often.

Mr. Hetzler: I might say that we have slip switches where they are used for the train to go over, that is where there is no switching to speak of over them, and I have never known of a derailment on them which was caused by the switch.

Mr. Sperry: I understand the objection to the slip switch is derailment of the car on the center frog. We had an experience in that connection on our main line. We had a center frog, no slip switch used in connection, simply crossing frog right at the head of our Mantua yard at Philadelphia. We could not keep our freight cars on the track. They would go off this center frog. After we put in a movable frog properly interlocked there was no further trouble.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

CEMENT VERSUS FROST.

By Cecil B. Smith, Ma. E., M. Can. Soc. C. E.

(*Transactions of the Can. Soc'y of Civil Engineers.*)

"The blowing test advised by Faija has detected a 'blowey' tendency in several instances; but much late evidence seems to throw some discredit on blowing tests, whether made with hot or boiling water, on the ground that manufacturers can, by the addition of sulphate of lime, cause the cement to be so slow setting and set so strongly as to resist the blowing tendency of so much as three per cent of free lime added after the cement had been burnt. If this is a fact, chemical analysis will need to be resorted to more frequently, to detect this dangerous adulteration which is fatal in sea-water and bad in any case, as the great strength which it gives to cements at early dates is apt to decrease at longer periods. Belgian No. 19 cement tested gave higher results at one week than at four weeks; this looks a little suspicious."

* * * * * * * * *

Moreover, tests made on No. 1 natural cement (see Series III, frost tests) show that while it cannot be immediately exposed to extreme cold, yet when it is exposed, after it has set, it will resist frost thoroughly, and become stronger than if immersed in water at an ordinary temperature. There are thousands of situations where natural cement mortar, 1 cement, 2 sand, will be found amply strong for the purposes required, in which case it will be found cheaper than Portland mortar, 1 cement, 3 sand. Referring ahead to Series III (frost), it will be seen that if mortars are tested in open air, the Portlands are weaker and naturals stronger than if the briquettes had been under water. This is a point of much importance, because if work is to be done which will not usually be submerged, as in damp foundations, abutments on land, culverts, etc., then tests made in open air will give results more favorable to naturals. In so many words our standard tests say: "Let us test all hydraulic cements under water; whether the mortar as used will be so or not, we will be on the safe side." This, as a generality, is doubtless best; but if we consider what a large proportion of cement is used in situations usually not submerged, it would seem more rational to test cements under conditions similar to those under which they are to be used in each case, be it in water or air.

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Series III.

FROST OR EXPOSURE TESTS.

This series consisted of various investigations into the strength of mortars when mixed with different conditions of water and under different exposures, reference being particularly made to frost. All tests were made in quadruplicate.

The first set was submerged, after 24 hours, in water of laboratory tanks.

The second set was kept on damp boards in a closed tank for the whole period, and never allowed to dry out.

The third set was allowed to set in the laboratory, and then exposed to the severe frost and left in open air for the whole period.

The fourth set was exposed in from 8 to 10 minutes to the severe frost, and left there for the whole period, except to take them out of the molds when they were set or frozen.

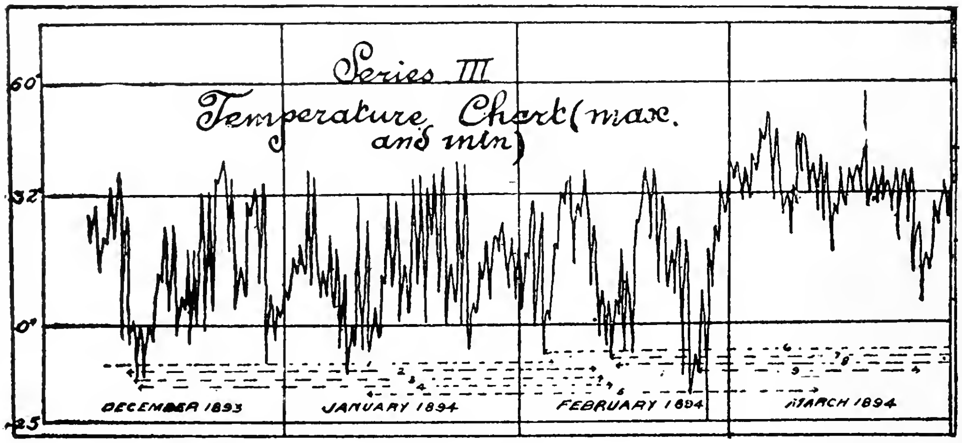

FIG. 152.

Table XL is given here, showing the results obtained, and accompanying it is a temperature chart showing the weather to which these mixtures were exposed during their whole period.

It will be noticed that these tests were purposely made in cold snaps so as to make the tests as severe as possible.

It would appear improbable that mortar immediately exposed to severe frost would become stronger than that allowed to set in a warm atmosphere, but the results of all the Portland cement tests, both in tension and compression (with one exception), assert it; and also that those allowed to set in the laboratory, and then exposed continually, are the weakest of all the four conditions treated of. This would go far to dispute the advisability of covering up mortar laid in frosty weather.

The next deduction from the Portland cement tests is that laboratory tests made with briquettes submerged give higher results than can be expected in open air work, and therefore that engineers should add this to the various other degenerating contingencies, such as bad mixing, dirty sand, etc. A deduction not much evi-

MIXTURE.	AGE.	TENSILE STRENGTH. Water Test (1)	Damp-Air Test (2)	Exposure after Setting (3)	Exposure before Setting (4)	COMPRESSIVE STRENGTH. 1	2	3	4	DATE OF EXPOSURE.	Temp. of Exposure for 3.	Temp. of Exposure for 4.	Time from Mixing till Exposure.	Natural Time of Setting.	No. of Tests.	REMARKS.
No. 11 Portl'd Neat	2 mos.	602	471	282	334	—	—	—	—	Dec. 6 to Feb. 6	+23°F.	+22°F.	30′ (3) 12′ (4)	25′	16	
1 to 1	"	377	276	194	233	3200	1780	1600	1900	Dec. 11 to Feb. 11	+5.°F	+3½°F.	40′ (3) 8′ (4)	35′	20	
2 to 1	"	168	150	105	111	800	720	660	440	Dec. 12 to Feb. 12	— ½°F.	0°F.	40′ (3) 10′ (4)	37′	24	
3 to 1	"	104	86	92	97	300	520	230	300	Dec. 13 to Feb. 13	— 5°F.	— 6°F.	1°27′ (3) 10′ (4)	1° 25′	24	Nos. 3 and 4 showed irregular and injured fractures.
No. 1 Natur'l Neat	"	226	221	349	0	1600	1500	2300	1390	Jan. 12 to M'ch 12	+ 2°F.	+ 5°F.	4°15′ (3) 11′ (4)	4° 15′	24	No. 4 tension completely torn in fragments.
1 to 1	"	125	229	187	44	—	—	0	800	Feb. 5 to April 5	+ 8°F.	+$\frac{6}{10}$°F.	8° 0′ (3) 10′ (4)	8° 00′	22	Some of No. 4 tension injured and No. 3 compression.
Neat	"	250	281	159	94	2800	2000	3300	1300	Feb. 13 to Apr. 13	+13°F.	+ 5°F.	6° 0′ (3) 10′ (4)	6° 0′	24	Mixed with water at temp. 122° F.
1 to 1	"	129	170	80	117	—	—	—	—	Feb. 14 to Apr. 14	+ 9°F.	0°F.	3° 0′ (3) 8′ (4)	2° 50′	20	Mixed with water at temp. 118° F.
Neat	1 mo.	155	278	217	249	—	—	—	—	Feb. 26 to M'ch 26	+17°F.	+7½°F.	7° 0′ (3) 9′ (4)	7° 0′	20	Mixed with 2 per cent. brine.

TABLE XL. FROST OR EXPOSURE TESTS. (Series III.)

denced in the table is that it is not safe to lay Portland cement mortar below 0 degrees F., because the third and fourth series of 3 to 1 Portland exposed at 6 degrees F. gave occular evidence that their structure was injured, and the test-pieces broke most irregularly, while the other exposures at about 0 degrees F. gave no evidence of any injury at all. Coming to the natural cement mortar in the 5th and 6th lines, we find much different results. The first one is decisive, and is that this particular cement mortar cannot be laid to zero weather. The first set was blown to pieces (except the cube), which surprisingly stood 1,390 lbs., while the second set, although not quite blown to pieces, showed extreme injury.

The most peculiar result is that this same cement, neat, if given a few hours to set in the temperate air, will on exposure to the frost attain a strength highest of the four conditions; this is quite remarkable, that while the Portland cement was strongest when submerged, the natural cement was stronger in damp air and strongest in frost.

Indeed, the Portland cement, in air, for 1 to 1 mixtures, was very little stronger than the 1 to 1 natural.

All of the natural cement specimens exposed to frost showed a disintegrated layer on the outside of about 1-8 inch thick; underneath this the structure was quite sound, and doubtless much of the variations in tests is due not so much to a weakening through the whole mass as to a reduced sectional area.

The last series made with 2 per cent brine in mild weather for one month (exposed at 7 1-2 degrees F.) showed that salt increased the strength, making them as strong as others were at two months when mixed with fresh water, and also again emphasized the advantage to this natural cement of open air tests.

It would seem that either hot water or salt are therefore very strengthening in their effect.

DISCUSSION.

Mr. Fred P. Spalding, M. Am. Soc. C. E., of Cornell University, said: * * * * * * *

Experiments made in the laboratory at Cornell University have shown that different brands of cement are affected very differently by the use of hot water in mixing. The writer has experimented upon about a dozen brands of cement in this particular, of which four were but slightly affected by the temperature of the water, giving much the result found by the author of the paper now under discussion. The others were all materially weakened by hot water, and three of them were rendered entirely worthless when the temperature of the water reached 120 degrees to 150 degrees F., the mortar never setting sufficiently to resist crushing under the pressure of the fingers. All of these cements were of good quality, and satisfactorily resisted the hot bath tests for permanence of volume.

* * * * * * * * *

Mr. C. B. Smith, said: * * * * *

The question of hot water is a very serious one, for its use is somewhat common amongst builders in cold weather. Since presenting this paper to the society, the author has tested briquettes made of 2 naturals and 3 Portlands, which were mixed with hot water, cold water, and salt water. Both in the laboratory and in frost tests he has found that the hot water weakened the Portlands and strengthened the naturals, the reverse being the case with salt water. Mr. J. G. Kerry has made a plea for chemical analysis, and doubtless this is a very necessary thing for some one to make, but it seems probable that, as a test, it will always be confined, in practice, to the manufacturer. Apropos of this is Mr. Perley's quotation from a letter of the late Henry Faija, which will make the point clear. Mr. Kerry objects to placing any positive value on specific gravity tests, and later on he would seem to place little reliance on strength tests; but we must really cling to something. It will not do to tear down without building up. In what way are we to satisfy Mr. Perley's demand for expeditious tests and Mr. Kerry's rejections of two of those in most common use? Fineness alone is no criterion. It is necessary to specify either specific gravity or strength. It is probable that either one of them, when coupled with fineness and soundness, is a sufficient guarantee of quality.

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CEMENT TESTS.

By Cecil B. Smith, Ma. E., M. Can. Soc. C. E.

(*Trans. of the Can. Soc'y of Civil Engineers.*)

PAPER II.

FROST TESTS.

In a previous paper, read before the society, the writer promised to place before its members the results of certain frost tests, which were being made at that time.

They are now given, in hope that they may be of some interest to those engineers who are contemplating the building of cement mortar masonry or cement concrete in cold weather.

Method of Procedure.—The briquettes were all made in the same manner, the 1 to 1 mixtures having 18 per cent of water, and the 3 to 1 mixture 15 per cent, being purposely greater than the amount used in ordinary laboratory tests, so as to get the mortar softer, and resembling more closely the condition in which masons use mortar in ordinary construction, as the effects of frost may be greater on soft mortars than on dry ones.

The briquettes were all rammed into the moulds in three layers, and the briquettes to be subjected to frost tests were immediately put outside on a window-sill. In a few hours, after the briquettes were frozen hard, they were removed from the moulds, and left exposed on the window-sill for two, three, or four months, care being taken to keep the snow swept off so as to allow the frost to have its full effect.

The tables given speak for themselves, and probably each engineer will draw special conclusions of his own; the writer will mention only a few points that seem obvious to him.

I. Four Months Tests.

It would appear, from these tests, that it is quite safe to build masonry work in November, in Montreal climate, when the materials are mixed and exposed to the air at about the freezing point. The proportion which the strength of the frost tests bears to the submerged ones is about that which would be obtained under the most favorable circumstances. The briquettes were all firm, smooth, and hard on the surface, and although subjected to four months severe frost in an exposed position, they did not seem to have been at all damaged.

II. Three Months Tests.

These were all made in December, and the coldest days were purposely selected. Yet the only briquettes which were blown in pieces were those made from two very inert, slow-setting, poor Canadian natural cements. The two other natural cements (one Canadian, the other Belgian) were quicker setting, and stood the test well. With the Portland cement, the diminution in strength is more apparent than real; the proportion of 90 to 164, which is the average of eleven brands, is really between briquettes $\frac{3}{4}''$ to $\frac{7}{8}''$ square, and briquettes 1″ square, the frost specimens being weathered off.

It is reasonable, however, that a briquette 1″ square exposed on three sides to the direct action of the frost, is rather more severely tested than mortar would be if placed in a wall; even the bottoms of the briquettes resting freely on the stone window-sills were largely uninjured, and the centers of all the briquettes appeared uninjured. As a result of these experiments, the writer would feel perfectly safe in laying cement mortar in December, with Portland or active natural cements, in weather 10 degrees to 15 degrees above zero, and in the most exposed situations, expecting in the spring to find $\frac{1}{4}''$ to $\frac{1}{2}''$ disintegrated at exposed joints, and needing repointing, or, better still, the pointing could be left till spring, and done once for all.

III. Two Months Tests.

These tests were much more severe in their natures; the sand and cement were exposed for hours in the open air, in small quantities, until they were absolutely down to the temperature of the outer air, and in the cold water and salt water series the water was also exposed until it was, in three cases, actually below the freezing point, being in a slushy condition.

These materials were put together in the laboratory as rapidly as possible, and exposed again at once, the usual interval being about six minutes, and the actual temperature of the mortar just before exposure having reached about 33 degrees or 34 degrees F., while in the hot water tests the mixture rose on an average of 58

degrees or 60 degrees, just before exposure, which was just about laboratory temperature.

The experiments are hardly extensive enough to be fully conclusive, being made only on seven brands of cement, but they point clearly to the advantage of the use of salt. Those briquettes made with salt showed good strength and little injury; although made with materials at low temperature exposed in severe cold, they seemed to be chiefly affected only on the surface.

On the other hand, the use of hot water does not seem to be of any advantage, particularly in Portland cements; a reason advanced by one writer for this fact was, that the bringing together of materials in a mortar, at widely divergent temperatures, exerted a prejudicial effect on the cement, hindering proper crystallization, and that the use of materials at as nearly as possible the same temperatures would produce more rapid and stronger action. The effect of hot water on natural cements is not so disappointing, but does not show much increase over the strength of similar specimens made with cold water.

The general results of these experiments, to the writer's mind, points to the idea that in any weather, in winter not extremely cold, say not lower than 15 degrees F., masonry work can be laid with cold sand, cold cement and cold water, provided the natural time of set of the cement is not more than five or six hours, and that by the addition of about 2 or 3 per cent of salt to the water, the same work may be done in weather down as low as zero, which is as cold as men will work. The disintegration will not extend probably deeper than $\frac{1}{4}''$ to $\frac{1}{2}''$, the remainder of the mass being quite sound.

FLOW OF WATER IN 48" PIPE.

By Desmond Fitzgerald, M. A. Soc. C. E.

(*Proceedings of American Society of Civil Engineers, January, 1896, p. 1.*)

These experiments were made in 1894 and 1895 on the Rosemary siphon, which constitutes part of the Sudbury aqueduct supplying the city of Boston with water. The pipes had been in use sixteen years; additional interest was attached to the experiments because Mr. F. P. Stearns, M. Am. Soc. C. E., investigated the discharges of these pipes when new.

The Sudbury aqueduct is 17.4 miles long, the greater portion of it having a section 9 feet wide and 7 ft. 8 in. high. At a distance of 11.7 miles from its head the water is carried across the valley of the Rosemary brook through two 48" cast iron pipes, 1,800 feet long, forming an inverted siphon which descends 50 feet below the ends. The pipes were laid in 1877 and brought into use in 1878. They are socket and spigot pipes, cast in 12 ft. lengths, and coated with Dr. Angus Smith's coaltar preparation. The losses of head were measured by piezometer tubes, screwed into the sides of the pipes near to the two ends of the siphon, their distances apart being accurately measured.

It was found impossible to arrange a weir in the aqueduct, near to the siphon, that would admit of greater velocity than 3.7 feet per second through one pipe. The flow through each pipe up to this velocity was measured in turn, then the tubercles were scraped off one pipe and further experiments made with the cleaned pipe. To continue the experiment at a higher velocity the above weir was removed and two weirs were erected at the terminal chamber of the aqueduct, 5.3 miles distant. By this means velocities up to 7.25 feet per second were obtained in the cleaned pipes, and velocities up to 5.5 feet per second in the tubercled pipes.

The levels of the waters over the weirs were read by means of hook gauges, with the zeros carefully adjusted to the level of the lips of the weirs, and their discharges were reduced in accordance with Bazin's experiments.

To compare these experiments with those made by Mr. F. P. Stearns in 1880 the following table was prepared:

Velocity.	Stearn's Valve for C for New Pipes.	Fitzgerald's Valve for C for Cleaned Pipes.
3.74	70.1	70.0
4.96	71.0	70.9
6.19	72.0	71.6

In the Chezy formula, v equals $C.\sqrt{di}$, where v is the velocity in feet per second, d the diameter in feet, and i the virtual gradient, for the tubercled pipe the experiments gave c equals 55.2, but for the cleaned pipe c varied with the velocity and was expressed by the formula c equals 65.9 v 0.045.

The following formulas were found to best fit the experiments, and were arrived at by the method of logarithmic homologues:

For cleaned pipes........ v equals 85.6d$\frac{1}{2}$ i 1-1.9

For tubercled pipes...... v equals 55.2d$\frac{1}{2}$ i $\frac{1}{2}$

THE INFLUENCE OF COLD ON THE STRENGTH OF IRON AND STEEL.

By Prof. M. Rudeloff.

(*Mittheilungen aus den königlichen technischen Versuchsanstalten zu Berlin, 1895, p. 109.*)

This paper contains an account of early investigations on the influence of cold on the strength of iron and steel, and an account of recent tests made in the imperial dockyard at Wilhelmshafen.

These later experiments were made on seven different materials, soft rivet iron, Siemens-Martin steel, basic steel, wrought iron—the three latter materials being in the form of angles—spring steel, cast steel, and wrought iron in round bars one inch in diameter. Of each material nine test pieces were prepared for tension, bending, and hammering. The experiments were made at three different temperatures, 18 degrees C., —20 degrees C., and —80 degrees C. The results of the tests are given in tabular form, and also a

number of diagrams showing the alteration with temperature of the stresses at the elastic limit, at the yield point, and at the breaking point.

The experiments show that the stress at the yield point, and also the breaking stress, is raised by cooling below 0 degrees C. The extension on fracture in general decreases on cooling; but the wrought iron round bar is an exception; in this case the extension on breaking increases with cooling.

The influence of cold on the amount of flow at the yield point is clearly shown, in each case this flow being greater at the lower temperatures. The spring steel and the cast steel show no decided flow at the yield point at ordinary temperatures, but at —20 degrees C. the flow is quite apparent, and at —80 degrees C. strongly marked. Similar phenomena are shown by the rolled wrought iron.

The results of the hammering tests show that at lower temperatures the materials investigated show greater resistance to alteration of form. The bending tests show that all the materials, except the rivet iron and the rolled wrought iron, are prejudicially affected by cold, the angle through which bending takes place without producing fracture being smaller the lower the temperature. The deterioration is most marked in cast steel and spring steel.

ELECTRIC INDUSTRY IN THE UNITED STATES.

Wm. Baxter, Jr., in Cassier's Magazine for November.

In the electric lighting field, the total capital invested in the United States is given as over five hundred millions of dollars. The number of plants, public and private, is over ten thousand. The number of motors in use is estimated at about five hundred thousand, and their value at about one hundred millions. The electrical apparatus used in mining is estimated at one hundred millions, and the value of the electric elevator industry will probably not fall short of fifteen millions.

The most important of all the electrical industries, however, is that of electric railways. In this field the investment is very great, and in the United States is represented by a capitalization of over seven hundred millions. The number of trolley cars in use is said to be over twenty-five thousand, and these run on over twelve thousand miles of track. The electric railways represent more than 90 per cent of all the street and suburban railroads of the country.

The aggregate of all the capital invested in electric lighting, electric railways and electric power is about fifteen hundred millions, and this does not include the value of the establishments that manufacture the machinery and apparatus. As many of these are among the largest industrial enterprises in the world, and as nearly all are concerns of considerable magnitude, it is very evident that their combined capital will run up into large figures.

Inasmuch as the electric light and power industry represents an investment of about fifteen hundred millions, without counting the value of the concerns that manufacture the machinery and supplies, it is evident that to estimate the total investment in every department of the electrical industry at two thousand millions of dollars in the United States alone, is not extravagant, for this would allow only five hundred millions to cover the value of the telegraph, the telephone and the almost unlimited number of electrical manufactories, large and small, that can be found, from one end of the land to the other.

ARTIFICIAL FUEL.

John R. Wagner in Cassier's Magazine for November.

In America the manufacture of artificial fuel is limited to that of eggettes, almost exclusively made for domestic use. The question of economic storage has been entirely omitted. In Europe, one of the advantages claimed for briquettes is that a greater weight can be neatly packed on locomotive tenders and in the holds of vessels and when properly made they produce no smoke in combustion.

Eggette or ovoid fuel, in distinction from briquette, may be considered somewhat of a luxury for domestic use, similar to that which anthracite coal bears to bituminous. In Europe, the convenience of the fuel for the furnace was not so much considered as the ability to produce a fuel which was cheapest and best suited for handling, storage and transportation. Much greater stress than in America was laid on the thorough preparation of the coal, on the quality of pitch or binding material used, and on the size of blocks giving the greatest economy in manufacture and handling.

The systems of preparing the coal for coking and briquetting, by washing or jigging, originated in Europe and have there been long practiced to such an extent that almost throughout the whole of the continent, coke can be guaranteed to contain only a certain per cent of ash. This difference in the art of washing fine coals may, to some extent, account for the slow progress made in the manufacture of briquettes in America.

Statistics show that the production of briquettes in 1893 was as follows:

	Tons.
France	1,750,000
Belgium	1,200,000
England	850,000
Austria	250,000
Germany	1,230,000
Italy	560,000
Spain	100,000
Russia and Sweden	100,000
United States	100,000
China, India and Canada	150,000

The proper mechanical preparation of the coal goes far toward making the briquetting of an otherwise waste of coal successful and profitable. That the thorough washing or freeing from all slate and other impurities is one of the chief factors in determining the value of the product is obvious, since the value of the fuel depends mainly on its freedom from ash, or the amount of available combustible matter it contains. This is especially important where the fuel is to be transported and an extra cost is added for handling and transportation.

HYDRAULIC DREDGING.

A. W. Robinson in Cassier's Magazine for November.

The special advantage of the hydraulic dredge is the transportation of the dredged material and its delivery at a considerable distance. It is especially applicable to land reclamation where the material has to be spread over considerable areas of low-lying land. This class of work is performed by the hydraulic dredge at a very low cost, because it combines in one operation the work of dredging, transporting and evenly spreading the material.

The Suez Canal could now be duplicated for about one-third of its cost. The Nicarauga Canal, although entirely different as to its conditions, can be built for a less sum to-day than was before thought possible. The reclamation of the vast areas of Marsh land which are now lying idle in many localities, has become not only a possibility, but commercially profitable because of the low cost at which they can now be filled in.

In general terms it may be said that the hydraulic dredge is adapted to work under conditions where the material is homogeneous, that is to say, free from large obstructions, and where a fluid or semi-fluid discharge can be provided for. This discharge may be at any distance up to a mile or more. By homogeneous material is meant sand, clay, earth, gravel, alluvial deposit, and, in fact, anything that does not contain large obstructions, such as boulders, roots or stumps, etc., and any material which can be disintegrated by plow or cutter. All such material is capable of being carried through a pipe, when mixed with from 60 to 90 per cent of water, the amount that can be carried in suspension depending on the distance, velocity of flow and character of material. Stones and other objects of considerable size can be washed through the pipe; in fact, any solids can be carried that will pass through the openings of the pump.

The form of pump commonly employed is the centrifugal. For dredging purposes this is made extra heavy; the internal passages should be large and free, and with curves of large radius. The interior of the pump is sometimes fitted with lining plates to take the wear and abrasion. This wear, however, is not great, and a well-designed dredging pump is about as durable as any other kind of dredging machine.

Western Society of Engineers,

ROOMS, 1737 MONADNOCK BLOCK,

CHICAGO, ILLS.

OFFICERS FOR 1896.

PRESIDENT,
John F. Wallace.

FIRST VICE-PRESIDENT,
Thos. T. Johnston.

SECOND VICE-PRESIDENT,
Alfred Noble.

TRUSTEES,

Robert W. Hunt,
G. A. M. Liljencrantz,
Horace E. Horton.

TREASURER,
Emil Gerber.

SECRETARY,
Nelson L. Litten.

STANDING COMMITTEES,

Membership: Alfred Noble, Horace E. Horton, E. Gerber.
Finance: E. Gerber, L. P. Morehouse, Hiero B. Herr.
Publication: J. J. Reynolds, Thos. T. Johnston, Chas. E. Billin.
Library: G. A. M. Liljencrantz, John Lundie, Frank P. Kellogg.

COMMITTEE ON PROFESSIONAL PAPERS,

John Lundie, J. W. Cloud,
A. V. Powell, E. L. Cooley,
W. L. Stebbings, G. M. Basford,
A. M. Feldman, G. L. Clausen,
W. D. Hotchkiss.

ENTERTAINMENT COMMITTEE,

Geo. P. Nichols,
C. E. Schauffler,
T. L. Condron.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—AUGUST 19, 1896.

A regular meeting of the Society (the 347th) was held in the Society's rooms at 8 P. M., Wednesday, August 19 1896. In the absence of the President, Vice-President Alfred Noble called the meeting to order.

The paper of the evening "Notes on Coal," was read by the author, Mr. C. F. White, who explained various points with drawings and the blackboard. Considerable additional information was brought out by the discussion. On motion a vote of thanks was given Mr. White for his interesting presentation of the subject.

The Entertainment Committee was complimented by a vote of thanks for providing the pleasant excursion down the Drainage Canal August 15th, and a like expression of appreciation was extended to the Atchison, Topeka & Santa Fe R. R. Co , for generously furnishing a train for the excursion without charge. On motion the meeting adjourned.

REGULAR MEETING—SEPTEMBER 2, 1896.

A regular meeting of the Society (the 348th) was held in its rooms at 8 P. M. Wednesday, September 2, 1896 President John F. Wallace in the chair, with twenty-six members and guests present.

The minutes of the previous meeting were read and approved.

Mr. C. D. Hill then read his paper on "Street Pavements in Chicago," which was followed by a general discussion of the adaptability of various materials and the best methods in using them.

On motion the meeting adjourned.

REGULAR MEETING—SEPTEMBER 16, 1896.

A regular meeting of the Society (the 349th) was held in the Society's rooms, 1736-9 Monadnock Block, Chicago, at 8 o'clock, Wednesday evening, September 16, 1896.

In the absence of the President and Vice-Presidents, Mr. John Lundie was elected to the chair.

Present, thirty-four members and guests.

The minutes of the previous meeting were read and approved.

Mr. H. C. Alexander was called by the Chairman and read a paper on the subject of the evening, "Parks and Roads." The Secretary then read a paper on the same subject prepared by Mr. J. F. Foster, who was unavoidably absent. Both papers were practical and interesting and called forth discussion by Messrs. Johnston, Bley, Alexander, Maddock, Kellogg, Hill and Davies.

A vote of thanks was tendered Messrs. Foster and Alexander.

On motion the meeting adjourned.

REGULAR MEETING—OCTOBER 7, 1896.

A regular meeting of the Society (the 35cth) was held at Armour Institute, at 8 o'clock Wednesday evening, October 7, 1896.

In the absence of the President and Vice-Presidents, Mr. J. J. Reynolds was elected to the chair.

Present, one hundred and three members and guests, including ladies.

The reading of the minutes of the previous meeting were dispensed with.

Mr. T. L. Condron presented a paper on "Steel for Boilers and Fire Boxes," illustrating special features with stereopticon views.

At the close of Mr. Condron's paper, Mr. H. F. J. Porter gave an extended talk on "Steel Forgings," based on the practice of the Bethlehem Iron Co. By the aid of the stereopticon some fifty views were given of the machinery, and various processes adopted by that Company in turning out forgings. Owing to the late hour discussion on the two papers was postponed till next meeting.

On motion the meeting adjourned.

At a Board of Direction meeting held at 2 P. M. Saturday, October 10, 1896, application for active membership was received from Franklin Pierce Dobson, and referred to the Membership Committee. The resignation of S. B. Jamieson was received and accepted to date December 31, 1896.

NELSON L. LITTEN, Secretary.

REGULAR MEETING—OCTOBER 21, 1896.

A regular meeting of the Society was held (the 351st) at 8 P. M. Wednesday, October 21, 1896, in the rooms of the Society, 1737 Monadnock Building. Vice-President T. T Johnston in the chair, with forty four members and guests present.

On motion. the reading of the minutes and the report of the Board of Direction was dispensed with.

There being no reports of standing committees, and no discussion of the papers presented at the last meeting, the Chair declared new business to be in order.

Mr. Alfred Noble—The Society, those of us who were so fortunate as to go, has just returned from the most enjoyable trip the Society ever had. The credit for this is due not only to our most efficient entertainment committee. but to our many hosts on the trip, whose cordial hospitality and unremitting courtesy should receive fitting attention at our hands. It is suggested that this take the form of a letter addressed to the different corporations to whom we are so much indebted, and I am about to read a letter which is offered as a suggestion to this end. It is proposed that a copy of this letter be sent to each of our hosts and spread upon the records of the Society.

CHICAGO Nov. 5, 1896

Dear Sir:—The good right hand of fellowship having been so cordially extended to the membership of this Society by their several hosts, all fellow workers in constructive and creative art, during our recent excursion to the Bedford Stone Quarries and to the Louisville Cement works, it is our duty to make recognition of the extraordinary courtesies tendered on this occasion in such manner as our present opportunities permit.

We cannot avoid a feeling of pride that individuals and corporations of energy, business capacity and intelligence, should hold our organization in the high esteem manifested by their hospitality and their painstaking efforts to exhibit their magnificent properties and sterling products These attentions show the respect in which our profession is held and point out the responsibilities resting upon it.

To those whose efforts were joined for our entertainment on this occasion we gladly acknowledge our obligation and our hearty thanks are therefore tendered to you, as one of our hosts We reciprocate most cordially your friendly feelings, and we will join you in advancing in every proper way, the art to which you and ourselves are devoted.

The Society has resolved that this letter be addressed to you by our proper officials and that a copy thereof be entered in our records.

If it meet the approval of the Society, I wou'd move that this be referred to a committee, to be revised and forwarded to the proper people. Seconded.

The Chair—Will you name the number?

Mr. Noble—I suggest that a committee of three be appointed by the Chair.

The chair put the motion to vote and the same was then and there declared carried.

The chair appointed the following to serve on such committee: Mr. Alfred Noble, Mr. Isham Randolph and Mr. Hiero B. Herr.

Mr. Randolph—I wish we had some one as gifted as John Bunyan to write of this Pilgrim's Progress of this Society. It has been a most delightful occasion to us all. We have enjoyed at the hands of the stone companies in the Bedford regions a hospitality which will long be remembered. We have seen there stone beds from which the Egyptians could have taken obelisks to equal any which are now left in old Egypt. We have passed on from there to Louisville and we have been entertained by the cement companies with royal hospitalities and seen their method of manufacture, and we have partaken of the good things which they spread before us without stint.

But while thanking our hosts, we must not forget our own committee of entertainment The energy and untiring labor bestowed upon this excursion by this committee of entertainment, Mr. Schauffler, Mr. Condron and Mr. Nichols, is deserving of the lasting gratitude of this Society, and I know that I speak the feelings of my associates when I propose that a vote be taken to thank those gentlemen. And while remembering them, I cannot forget the aid which was rendered and the assistance which was given them by all their untiring lieutenants, Mr. J. J. Reynolds and Mr. T. T. Johnston. In speaking of the latter I feel almost as if I were praising one of my own family, but I must do it on this occasion. I move that a vote of thanks be extended to the committee and the two gentlemen last named.

Prof. Whitney—I should like to second heartily everything that has been said. It is quite evident that the exhilarating effects of our entertainment down there have not quite passed off from a number of us. I am glad to see Mr. Randolph showing the effect.

I rise also to thank this committee and all those corporations who together made it possible to have such a delightful trip, particularly on the part of those members of the Engineering Faculty of the University of Wisconsin who attended, and also for the host that came down from the North in the shape of the twenty-five senior engineers. I do not think any of the gentlemen who attended that trip will have retained with them so bright a spot in memory as these young men will retain, each of them, throughout life, from the fact that our ordinary week of inspection down here has so far expanded and been so gloriously filled during those first two days, and I want to thank the committee particularly for myself for all they have done for me as an individual apart from the others.

I should like to say that the whole twenty-five students are not here, still I think that every one present would like to say "thank you," in some way. I think if you will call on Mr. Broenniman he would voice the sentiments of the students.

The Chair—We would be glad to hear from Mr. Broenniman.

Mr. Broenniman—Mr. Chairman and gentlemen of the Western Society of Engineers: It gives us great pleasure in being able to show some appreciation of the favors which you have extended us. It is not always that such a privilege is offered to students who are out on an inspection trip, and, as the fortunate ones, we would like to express our thanks to the members of this Society for the hospitality which they have manifested. It is not only that we had great pleasure in visiting these different places along the route of the trip, but we have had the pleasure of meeting the members of this Society and of becoming acquainted with the members of our chosen profession. The recollections of this trip, as Prof. Whitney has said, will long remain with us, and connected with it we will always remember the hospitality of this Society and the hospitality of the hosts on the trip. We know of no other way to repay these privileges, but, as a unit, to express our most sincere thanks to the Society.

Prof. Turneaure—I wish, on behalf of the construction force who were present as guests, not as members of the Society, to extend our thanks to the Society for the delightful excursion we have had.

The Chair—I think I may say to the gentlemen from the University of Wisconsin in behalf of the Western Society of Engineers, that we were greatly pleased to have the members of the faculty of that university and the young men who accompanied them with us. It is a duty we owe to young engineers,

because as young men most of us received favors of the like, and we have no doubt that when they have served a number of years in their profession, that they may be called upon to perform a like duty. I may say again that you were all welcome a thousand times.

Is there any further discussion in connection with the motion made by Mr. Randolph?

Mr. Reynolds—It might be well, as there are a good many members here who did not have the privilege of going down there and enjoying themselves, and who are hearing of all the good things that we enjoyed, which they could not enjoy, it might be well to pass a vote of regret that they did not go. (Laughter.)

The motion of Mr. Randolph was then put to vote and unanimously carried.

Mr. Randolph—The fountain of gratitude is still flowing, and we do not want to forget that it was an interstate occasion; we enjoyed a long haul, a free haul, and it was all due to a short Hall (called Ferd by his friends) that we got it, and I move that a vote of thanks be extended to our comrade, Mr. Ferd Hall, for his successful efforts in securing the train for us.

Mr. Evans—I would suggest that the yard plans of the different railroads of the cities might be interesting to the members, and I would be glad to furnish the plans of the Northwestern system in the city and would suggest that others do the same of their railroads and have them on file and accessible to members interested in the subject. I think as a matter of comparison the different problems that are presented by the different yards would be a good thing for the Society. Most always there are local conditions with each yard that the plan would explain, and some one might fit a project that a man had on hand very nicely, help him out and be a matter of information. I will be glad to furnish what the Northwestern have, and I think that others ought to do the same.

The Chair—I think that suggestion is a very happy one.

Mr. Hetzler—I am certain the C., B. & Q. would be glad to follow out the same line.

The Chair—The suggestion brings up another idea, that perhaps our Publication Committee, now that we have our own journal, might take hold of and develop a symposium on railroad yards. That would do for one of the early numbers in the year; perhaps we might get one number devoted entirely to that subject.

Mr. Reynolds—Such a number would have very great value for more people than railroad people.

The Chair—I think the Publication Committee might do well to consider that matter.

The Chair—The chair has been somewhat at a loss as to what disposition to make of the suggestion made by Mr. Evans with reference to collecting plans of various yards about Chicago. In the absence of any motion in the premises the chair will undertake to present the matter to the Board of Directors at its next meeting with a view to carrying out the suggestion. If there are any motions to make in that connection I will be glad to hear them however

Mr. Randolph—I think it might very safely be left to the Board of Direction.

The Chair—If there are no motions in that connection we will pass to further discussions or questions, or if there are no questions and discussions a motion to adjourn will be in order. Has Mr. Nichols any announcement to make this evening?

Mr. Nichols—The committee has made partial arrangements for an excursion to Rock Island to view the new government bridge from Rock Island to Davenport, also to look over the water power and visit the arsenal It seemed to the committee that it would be a matter of interest to make that trip. The committee has interviewed the Rock Island Railroad and find they are disposed to tender us a train service, that is, either sleepers for us or take us down by coaches. This excursion we thought might take place perhaps the 6th and 7th of next month, going down perhaps on Friday night, spending Saturday there and returning Sunday morning. Really no particular arrangements have been made, but the committee have looked into the matter and know what we can do if it is desirable to make that trip.

The Chair—The prospect is certainly a very pleasant one. I expect that the

committee will find verified an old saying that "nothing succeeds like success." We have had some success and we will have some succeed perhaps.

Mr. Randolph—We have with us two distinguished professors from the University of Wisconsin. We would be glad to hear from them on the inspection tour which they have been making, and perhaps they can give us some interesting points to look into around our own city.

The Chair—The suggestion is a very good one; Prof. Whitney, Prof. Turneaure and others are here, and we would like to hear from them.

Prof. Whitney—Mr. Chairman, we spent a very delightful week down here, the first few days accompanying you on that trip, but it makes us from up the country hustle to keep up with the progress, much less give any points. We have enjoyed this meeting very much and what we have heard regarding these yards. I wish we could attend more meetings and see more of the members of our profession. We are sorry that we are about 160 miles away from here. I have no pointers to give any members here. I think, perhaps, Prof. Turneaure might be more successful.

Prof. Turneaure—I do not think I have anything to say. We came down here to Chicago to see what you were doing, and I am sure you know what you are doing better than we do.

On motion the meeting adjourned.

NELSON L. LITTEN, Secretary.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid materially in completing valuable volumes for our files.

Since the issue of No. 4 of the Journal we have received the following as gifts from the donors named :

Armour Institute—The Official Gazette—Volume 63, April 4 to June 27, 1893.
" " " " 64, July 4 to Sept. 26, 1893.
Iron Age, Aug. 28 to Dec. 25, 1890.
" " 3 to Oct. 19, 1893.
David L. Barnes, C. E.—Electric Locomotives.
W. W. Salmon, C. E.—9 copies Zeitschrift des Vereines Deutscher Ingenieure.
Charles S. Hill, C. E.—The Chicago Main Drainage Channel.
Chicago Sanitary District—Proceedings of Trustees for 1895.
American Society of Heating and Ventilating Engineers—Transactions, 1896.
Northeast Coast Institution Engineers and Shipbuilders—Transactions, 1895–6.
State Board of Health, Mass.—Report for 1895.
A Friend—Railroad Bridge Specifications.
Timber Physics, Part I and II, U. S. Dept. Agri., 1892–3.
4th Annual Report U. S. Geo. Survey, 1892–3.
Gear List, Hydraulic Cable, Power-Transmitting Machinery, } by Walker Manf. Co.
City Engineer of Boston, Mass.—29th Annual Report, 1895.
Various friends—200 periodicals, 1895–6.

The Library and Reading-rooms are open from 9 a.m. till 5.30 p.m. on week-days, except Saturday until 3 p.m.

Journal of the Western Society of Engineers.

The Society, as a body, is not responsible for the statements and opinions advocated in its publications.

VOL. I. DECEMBER, 1896. No. 6.

XVIII.

THE ROCK ISLAND EXCURSION.

BY THE PUBLICATION COMMITTEE.

President John F. Wallace received the following invitation from the officials of the Chicago, Rock Island & Pacific Railway in the latter part of October:

Chicago, Oct. 22, 1896.

Mr. J. F. Wallace, President Western Society of Civil Enngineers,
Illinois Central Railroad General Offices, City:

Dear Sir:—It has been suggested that a visit to the double-track railroad and highway bridge now in process of erection by this company and the United States government over the Mississippi River, between Rock Island and Davenport, would be interesting to the members of your society. I hereby, in behalf of the Chicago, Rock Island & Pacific Railway Company, tender your society a special train from Chicago to Rock Island and return, and ask you to be the guests of this company for the trip. The train will be furnished at such time and run upon such schedule as you may select. I would state, however, that by leaving Chicago at 8 a. m. your party could be returned to the city by 11 p. m. of the same day, and be given seven hours at Rock Island.

In addition to the bridge, the members of your society would doubtless find much to interest them by an inspection of the United States government arsenal at Rock Island, and for such a purpose I feel justified in assuring you the most cordial welcome from Colonel Buffington, the present commander.

Awaiting your pleasure, I am truly yours,

H. A. PARKER,
Assistant to President.

Messrs. G. P. Nichols, T. L. Condron, and C. E. Schauffler, the members of the entertainment committee, were assigned the task of perfecting the arrangements for the excursion, the invitation

having been formally accepted. Their announcement of program brought to the Rock Island station on the morning of November 7th between 170 and 180 members and ladies. The train left at 8:10 a. m. and reached Rock Island shortly after noon. Lunch was served at the Harper House, the party being the guests of the Rock Island Railway. Immediately after lunch the return to the train was made and departure taken for the United States arsenal on Rock Island proper, the courtesy of Colonel Buffington, U. S. A., having given the freedom of this institution to the party. The arsenal machinery is driven by water power derived from the falls, or rapids, of the Mississippi river, at either side of the island. While a portion of the party inspected the workings in the arsenal, the larger part inspected the water power. The water wheels and power transmitting machinery attracted much attention, but the point of greatest interest attached to the extension of the water power dam. The work is being done entirely in Portland cement concrete and is a radical step in the progress being

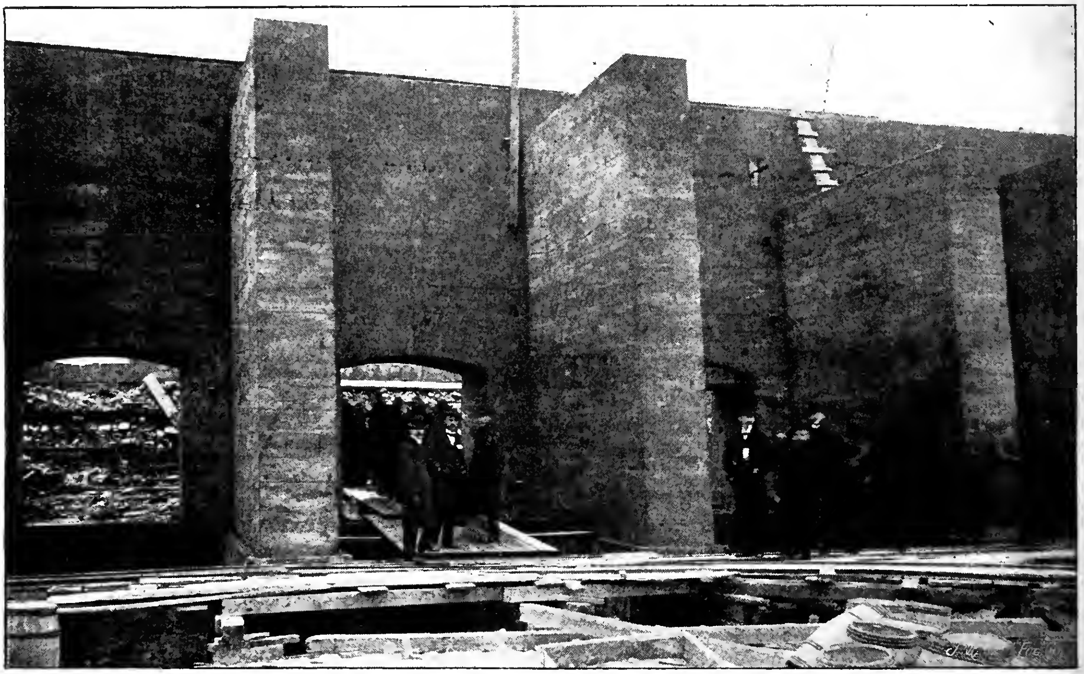


Fig. 153. Water-Power Dam.

made in the use of concrete. Our fellow member, Mr. C. E. Schauffler, may well feel proud that Empire Portland cement is being used to the exclusion of all foreign cements. Fig. 153 is a view of a part of the work, taken by Mr. B. E. Grant, member W. S. E. After watching for some time the making of the concrete and the placing of it in the forms, the party returned to the train and were taken at once to inspect the new bridge which was erected by the United States government and the Rock Island Railway

jointly, under supervision and design mentioned in what follows, which is taken from a souvenir presented by the Phoenix Bridge Company:

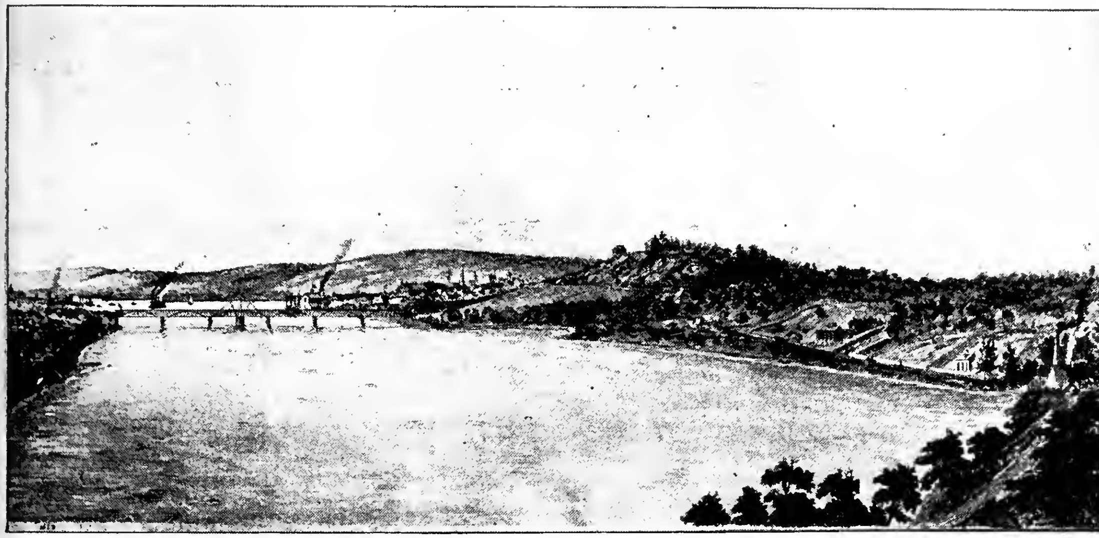


FIG. 154. FIRST BRIDGE OVER MISSISSIPPI RIVER, BUILT AT ROCK ISLAND IN 1853.

The first bridge between Rock Island and Davenport, Fig. 154, was built under a charter granted January 17, 1853, by the Legislature of the State of Illinois, for the purpose of connecting the Chicago & Rock Island Railway in Illinois with the Mississippi & Missouri Railroad in Iowa.

The contract for constructing the masonry was let September 26, 1853. On April 21, 1856, the structure was completed, and the first train, consisting of the engine "Des Moines" and eight cars, passed over it.

This was the first bridge built over the Mississippi River, and the opposition to its construction and maintenance by the so-called "river interest" was most bitter and prolonged.

On the 6th of May, 1856, the first span (250 feet in length) east of the draw was destroyed by fire, communicated by the steamboat Effie Afton, which collided with and burned at one of the piers.

In the litigation which followed, and which was brought by the owners of the boat, Abraham Lincoln, of Springfield, Ill., appeared as one of the counsel for the railway company.

April 3, 1860, in a suit brought in the District Court of the United States for the District of Iowa by James Ward, a citizen of St. Louis, Judge Love declared the bridge "a nuisance," and ordered "all the piers within the State of Iowa, together with the superstructure thereon, removed on or before the 1st day of October next," saying at the same time in his decree, among other things, that if this bridge were permitted to remain "* * * we shall probably

in no great period of time have railroad bridges upon the Mississippi River at every forty or fifty miles of its course"; also "that the loss involved in the removal of this bridge would be but trifling compared with the great mischief which must inevitably flow (to the commerce of the river) from the precedent of maintaining it."

The Supreme Court of the United States reversed this decree, principally on the ground that the jurisdiction of the District Court extended only to the middle thread of the main channel, and the removal of the three piers in the State of Iowa would not remedy the obstruction, while it would destroy the bridge.

The prediction of Judge Love has been fully realized. At this time there are at least thirty-five railroad or highway bridges over the Mississippi River between Minneapolis and St. Louis, a distance of about 800 miles.

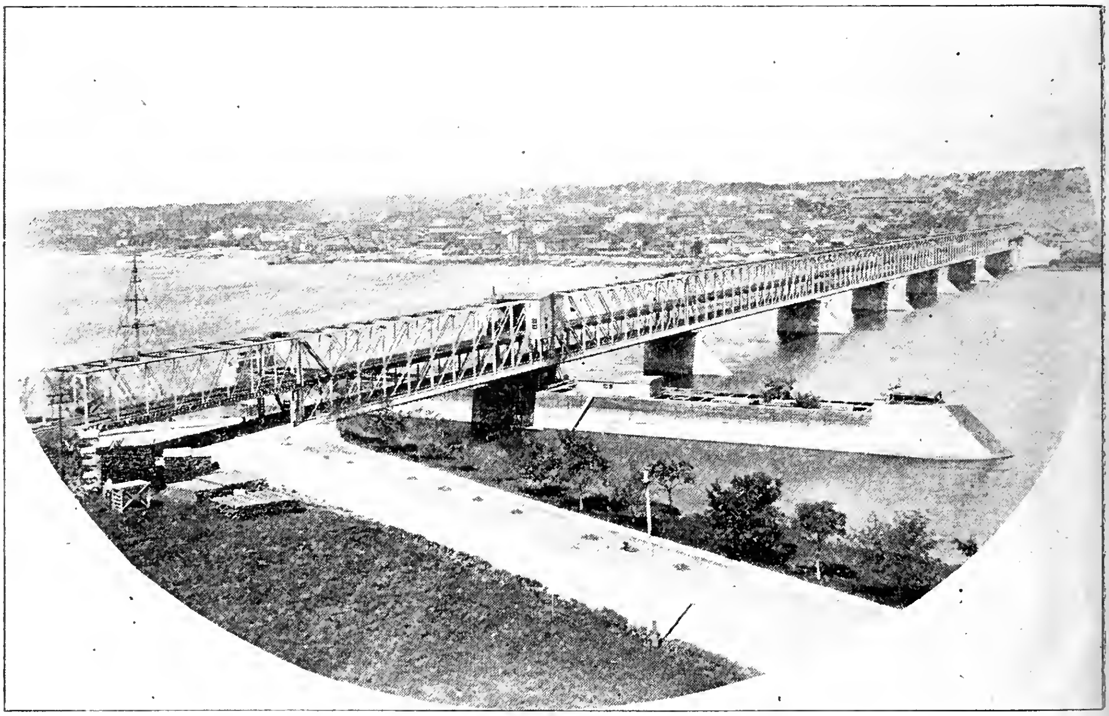


FIG. 155. SECOND BRIDGE AT ROCK ISLAND, C. SHALER SMITH, CHIEF ENGINEER. BUILT BY THE PHOENIX BRIDGE COMPANY IN 1870.

In March, 1868, with the opening of the river, the first pier from the Iowa shore was pushed bodily down stream some twenty or twenty-five feet by the ice; and in April of the same year, during a severe wind storm, the draw span was lifted from its masonry and blown over on its side up stream, so that it hung supported only by the draw pier, with both ends free in mid-air.

In 1866 and 1867 two acts were passed by Congress, authorizing the construction of a new bridge over the Mississippi River between

Rock Island and Davenport, providing for a new location of the railroad track on the island of Rock Island, and the removal of the original bridge from the river.

A contract for the masonry of the new structure was let June 9, 1869; the superstructure was built by The Phoenix Bridge Company. The bridge was completed and brought into general use in October, 1872.

Nineteen years later it was found necessary to strengthen the upper or railroad deck, and in the summer of 1891 the wooden system then in use was replaced by iron construction, the work being done by The Phoenix Bridge Company.

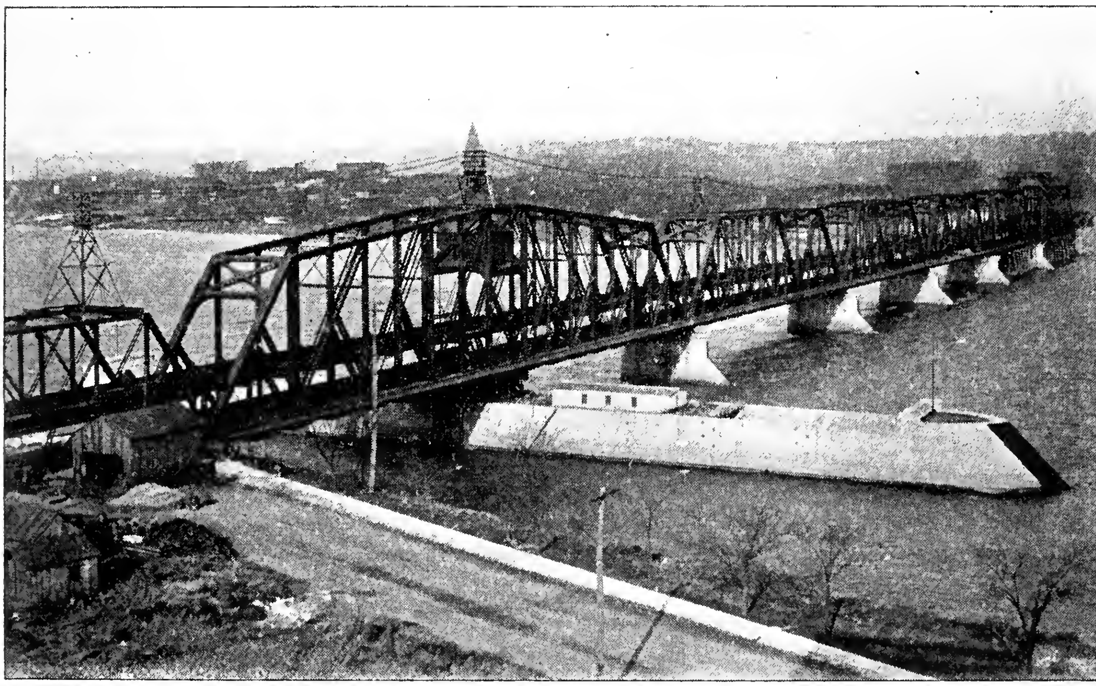


FIG. 156. THIRD BRIDGE AT ROCK ISLAND, RALPH MODJESKI, CHIEF ENGINEER BUILT BY THE PHOENIX BRIDGE COMPANY IN 1896.

In the winter of 1894 and 1895 an entirely new superstructure and partially new masonry were authorized, and the necessary appropriation made by Congress for the construction. Mr. Ralph Modjeski was appointed chief engineer, tenders for the work were received on August 12, 1895, at Rock Island Arsenal, by Col. A. R. Buffington commanding, and the contract subsequently awarded to The Phoenix Bridge Company.

The trusses of this bridge (Fig. 156) are calculated to carry a total moving load of 11,360 pounds per lineal foot, of which 8,000 pounds are on the railway floor and 3,360 pounds on the roadway floor.

The solid corrugated steel railway floor, together with the guard angles and rail plates, weight about 940 pounds per lineal foot

of the bridge. The draw span, which weights approximately 2,500,-000 pounds, is one of the heaviest ever built. The chain motion for moving this span is one of the departures from the usual methods.

The train stopped just before reaching the draw span, where the gentlemen of the party left the ladies to enjoy the more comfortable cars while they braved the rather chilly wind to examine the details of the work. The draw, which is operated by electrical power, was revolved twice in order that the mechanism could be seen in operation. The various details of the motive power were explained by Mr. G. P. Nichols, member W. S. E., by whom it was installed. The bridge will form the subject of a paper by Mr. Ralph Modjeski, chief engineer, to be read before the society at an early meeting. Further description will, therefore, be omitted at this time, except the following, which is taken from the issue of the Railway Age, November 27, 1896:

The draw span is the particularly noteworthy feature of the bridge. The operating machinery consists of five different devices, viz., the swinging machinery, the rail locks, the end jacks, the inter-locking and controlling system, and the emergency hand devices. The swinging is done by means of a cast-steel rack attached to the tread on the center pier, and having sprocket teeth. Two vertical shafts, one on either side of the bridge, supported by brackets and fitted with cast-steel sprocket wheels at the lower end, transmit the power to the steel rack by means of an endless chain carried by the sprocket wheels and engaging in the teeth of the rack. On the upper end of these vertical shafts are sprocket wheels, which are connected by a chain to a vertical driving shaft midway between them, which rises to the floor of the machinery room. An interesting feature of this part of the mechanism consists in the fact that all the vertical shafts are run on ball step bearings. By means of a train of gears, a 50 horse power electric motor is connected with the shafts, thereby transmitting the power to the rack below.

The rail locks consist of heavy steel slides fitted to the outside of the rails on the bridge with those on the fixed span, thus giving a continuous line of rail for the passage of the wheels. The slides are operated by means of a pneumatic cylinder located in the center of the bridge, all four slides at each end of the bridge, and both ends, moving simultaneously.

The end jacks are of the semi-toggle type, consisting of two parallel pairs of bars attached to the end beams, directly under the chords, by pins, so as to turn freely, while on the lower end are rollers which rest on bearing plates on the shore abutment. By means of a pneumatic cylinder, a center crank and struts connected to the roller pins, the jacks are forced to a vertical position when the bridge is closed, and are drawn to release the bridge when it is to be opened. For the interlocking a Hall signal is placed on each of

the fixed spans, within a few feet of the ends of the draw, standing normally at danger. Connected to each of the jacks and rail locks are electric switch boxes, which are also connected by wires to an indicator in the machinery room. When any one of the jacks or rail locks is in a closed position (or when all are), a red lamp is lighted in the indicator (one lamp for each jack or lock), and when the bridge is released to swing a white line is shown, replacing the red. The man in charge can set the signal to safety only when the end jacks and locks are set. Should, for any reason, the bridge not be properly locked, the engineer cannot receive his signal to enter upon the draw.

The controlling device makes it impossible for the operator to swing the bridge until first the rail locks and then the end jacks have been released. Emergency hand devices are provided, by which the bridge can be swung, in case, for any reason, the mechanism becomes inoperative. An air compressor, driven by an electric motor, is located in the machinery room, supplying power for the various cylinders.

Among the members of the party was Mr. Geo. P. Nichols, of the firm of Geo. P. Nichols & Bro., who were the contractors for the entire operating mechanism of the draw span, including the electric swinging apparatus and signal system. Mr. Byron B. Carter, mechanical engineer, also in attendance, designed the operating mechanism.

After viewing the structure fully the party was taken to the Kimball House, in Davenport, where they were assigned quarters and partook of dinner by kindness of the Rock Island Railroad. The evening was occupied variously, some of the members remaining at quarters, while others visited the water works, others the wrought metal axle works of W. P. Bettendorf; others visited a political meeting at Rock Island; others were entertained pleasantly at the clubs, and still others sought their friends residing in the vicinity.

The next morning the train was boarded at 9 o'clock and a visit made to the Hennepin canal, by invitation of Maj. W. L. Marshall, corps of engineers U. S. A. The train reached Milan, distant about six miles, when the party was taken in charge by Lieut. Col. W. R. King, corps of engineers U. S. A.; Mr. L. L. Wheeler, assistant U. S. engineer in local charge of the canal, and Mr. G. A. M. Liljencrantz, U. S. assistant engineer, member W. S. E. Two tow boats and a capacious barge conveyed the party through the canal, where the concrete locks and the Parker-Taintor gates were viewed. Mr. Wheeler kindly operated one of the gates. These works are quite fully described at page 2726, et seq., of the Report of the Chief of Engineers, U. S. A., for 1895, in a report made by Major Marshall. This inspection being done, return was made to Davenport, where the party became the guests of Mr. C. E. Schauffler. Dinner over, the train was boarded for the return to

Chicago, and the most exciting, if not the most interesting event of the excursion was at hand, viz.: a fast ride on the railway. The event is well worth recording, and occasion is taken to reproduce the account of the ride published in the Railway Age November 13, 1896:

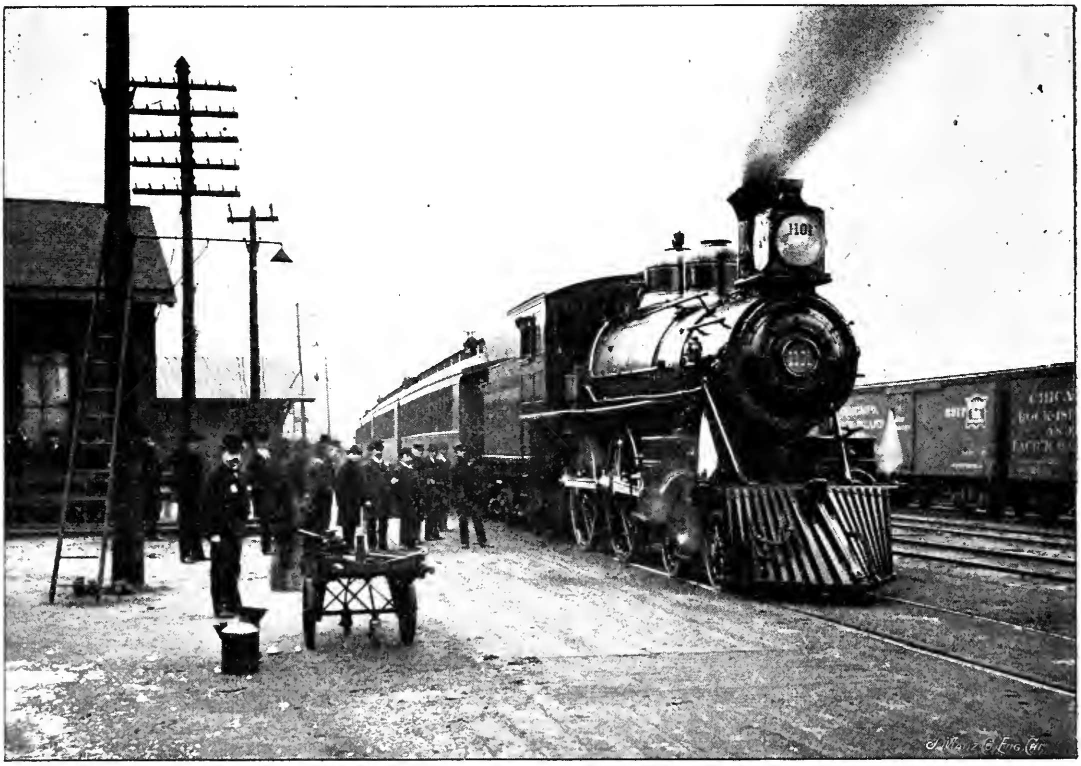


FIG. 157. ENGINE 1101 AND TRAIN AT ROCK ISLAND DEPOT.

At 3:04 p. m. Sunday the party started on the return. No preparation had been made for a trial of the speed of engine 1101. The passing of local trains and the stops made to accommodate the departure of many of the members interfered with the running, but between Moline and Bureau, where there is a tangent of twenty-six miles, several miles were made at the rate of seventy-two miles per hour, and a maximum speed was reached of 76.6 miles per hour. For a distance of thirty miles no mile was run at a less rate than sixty miles per hour. The party arrived at Chicago at 6:44 p. m., having made the run in 3 hours and 40 minutes. It is stated that without interruptions the engine could readily have hauled the train the total distance in three hours. An official of the Rock Island stated to a representative of The Railway Age that he is confident that the engine, with favoring conditions, can, with the same weight of train, five coaches, make 100 miles an hour.

Fig. 157 is a view of the train just before leaving Rock Island, and was taken by Mr. Grant. The elements of the locomotive,

1101, which was constructed in the Rock Island shops at Chicago, are as follows:

Total weight—123,000 pounds.
Cylinders—19 1-2x26 inches.
Weight on drivers—82,000 pounds.
Boiler type—Wagon top.
Boiler pressure—190 pounds.
Boiler diameter—61 inches.
Number of tubes—260.
Heating surface—fire box—193.3 square feet.
Heating surface—tubes—1,795.0 square feet.
Heating surface—total—1,988.3 square feet.
Grate area—24.5 square feet.
Maximum travel of valve—6 inches.
Lap—inside—None.
Lap—outside—1 1-8 inches.
Drivers, diameter—78 inches.
Drivers, wheel base—8 feet 6 inches.
Length of fire box—108 inches.
Tender, water capacity—4,300 gallons.
Tender, coal capacity—7 tons.

Those to whom our society is particularly indebted for the many kindnesses and courtesies attending the excursion are as follows:

Mr. R. R. Cable—President Chicago, Rock Island & Pacific Railway.

Mr. H. A. Parker—Assistant to President.

Mr. C. L. Nichols—Division Superintendent C., R. I. & P. Ry.

Colonel A. R. Buffington—Ordnance Corps U. S. A., Rock Island, Ill.

Lieutenant F. C. Horney—Ordnance Corps U. S. A., Rock Island, Ill.

Colonel W. R. King—Corps of Engineers U. S. A.

Major Wm. L. Marshall—Corps of Engineers, U. S. A.

Mr. L. L. Wheeler—U. S. Assistant Engineer.

Mr. C. E. Schauffler—Western Agent Empire Cement Co.

Mr. Ralph Modjeski—Chief Engineer of the Rock Island Bridge.

Mr. W. P. Bittendorf, Mr. Charles Francis, Mr. J. Charles Young—Civil Engineers, Davenport, Iowa.

XIX.

STEEL FORGINGS.

By H. F. J. Porter, Mem. W. S. E.

Read October 7, 1896.

Without some explanation at the outset it would seem almost presumptuous on my part to attempt to discuss the subject of "Steel Forgings" in its entirety in the short time that is allotted to me this evening. The subject is entirely too comprehensive and too general to be covered in a single evening's talk. It will only be fair to myself therefore, to state in advance the limitations to my paper, that you may not expect too much of me, and it will be fair to you, also, so that you may know beforehand that you will not be submitted to the strain of listening to a lengthy dissertation entering into all the details of the subject.

If, therefore, I state that the Bethlehem Iron Company has the most complete forge in the world, and that the processes adopted there for turning out forgings are far in advance of those in use in any other forge in this country and are thoroughly abreast with, and representative of, the best practice in forges abroad, and if I briefly review historically the development of the art of forging in this country, leading up gradually to the circumstances which caused the erection of this large forging plant, and then describe the processes in use there, I think that I will have covered about all that could be expected to to-night and that you will have heard about all that you would care to listen to.

Steel for use in the trades is comparatively new in this country. Twenty years ago it was not known here as a commercial product. The large rolling mills had only begun, at that time, to turn out rails and structural material made of steel. They had just made that change from iron, but they had not made it without examining fully into the reasons why a similar change had been made in the rolling mills abroad, and without long experimenting to satisfy themselves that such a change would be practicable here. Shortly after this change was made the manufacturers and builders in this country generally began to adopt steel in preference to iron. They found that it was a much more reliable material and that it was stronger and lighter, and having once appreciated its merits they began to demand it in place of iron for forgings in the trades. As soon, however, as they made a demand for steel forgings, they found an obstacle in the way of obtaining them from the fact that forges were not properly equipped to deliver them. There were two reasons for this. In the first place, there were no large commer-

cial enterprises in this country at the time which could have given an extended demand for large forgings. In the next place, whenever large forgings had been called for, they were of iron, and such forgings could be made in forges that were equipped with a smaller capacity than was necessary to turn out forgings made of steel. An iron forging is built up of small pieces and the property of welding, which iron possesses, is taken advantage of. A steel forging, on the contrary, has to be made from a steel casting larger than the finished piece, as steel does not possess the property of welding. It should be, in fact, twice its size in order that the proper amount of work necessary to make it a forging should enter into the metal during its reduction in size under the hammer. For instance, if you want a twelve-inch shaft, made of iron, it would be built up of small pieces, four or five inches thick, welded together. If, on the contrary, you should call for a steel shaft of the same size, best practice would require beginning with a piece of steel twenty-four inches in diameter and forging it down under a hammer whose blow can be felt through twenty-four inches of metal instead of only four or five inches, as in the case of iron; so you can readily see that, when the manufacturers called for steel forgings, in the first place the forges did not have the hammer equipment necessary to make them, and there were other ample reasons for their not being able to supply what was wanted, as you will appreciate when we view the processes which are now considered necessary for turning out good work. Many forges did not hesitate to supply, however, so-called "steel forgings," and although they have never fitted themselves up properly to this day, they have not hesitated to continue to supply the same thing ever since; but what has been supplied has not been, and cannot be, satisfactory, as I think I will make clear to you as we go further into the subject. The result is that a prejudice has unjustly been established in the trades against steel, and it has been kept fresh in the minds of the uninformed up to the present time to a great extent through these forges themselves, who have been unwilling to spend the necessary amount of money to equip themselves properly for turning out steel forgings.

It is evident that the Bethlehem Iron Company, possessing at that time rolling mills only, had appreciated the necessity for a place from which to order large forgings, for at the last meeting of the American Society of Mechanical Engineers in St. Louis, Mr. John Fritz, president of the society, who had been the superintendent of the Bethlehem Iron Company in those times, stated that he had preferred to use cast iron for large shafts rather than steel, and even than wrought iron, which was obtainable from the forges then in existence. He said that the wrought iron forgings that were furnished almost invariably had holes in their center caused by their being built up under hammers that were too light to make them. The impact of the blow of the light hammers in forging had affected

the surface metal only and drawn it away from the center, leaving cavities there. Such imperfect forgings he was unwilling to trust to the same extent as castings made sufficiently large to withstand the strains to which they would be subjected.

The Bethlehem Iron Company appreciated that before very long there would be a strong demand in this country for steel forgings, for about that time there was beginning to be a development in commercial enterprises and the government was thinking seriously of building a navy. They decided, therefore, to send a commission abroad to visit the principal forges that were in existence in Europe, and to report what recommendation they might have to make regarding the erection of a modern forge in this country. The commission consisted of their superintendent, Mr. John Fritz, and Lieutenant W. H. Jacques of the navy. After visiting the most representative forges in England, Scotland, France and Germany they returned and reported that the forge of Sir Joseph Whitworth & Co. of Manchester, England, was by far the best equipped for the manufacture of miscellaneous forgings, and that the forge of Schneider & Co. of Le Creusot, France, was foremost in methods adopted for the manufacture of armor plate. They recommended that these two forges be duplicated. Their recommendations were accepted and contracts were thereupon made with these firms respectively to carry them out. The money value of these contracts was very great and has rarely, if ever, been exceeded by that of single orders given by a private firm at any one time. This fact in itself is sufficient proof that the management was satisfied that they were working in the right direction. They were not satisfied, however, with merely duplicating these two plants, but, while the machinery was under way and being delivered, they decided to double the capacity of the tools they had purchased. The forges above mentioned were two of the largest then built. They were duplicated and their capacity doubled, so that when complete the new forge was easily the largest in the world, and since then additional equipment has been put in when necessity demanded, until it is by far the most complete forge in existence.

When the Bethlehem Iron Company built this forge they decided that they would turn out steel forgings only. There were various reasons for coming to this determination, but the principal one was that they had already passed through the stage where they had changed the product of their rolling mill from iron to steel, and they knew the benefit that would accrue to forgings by making them of steel also. I could go into various other reasons which determined them to adhere to steel and not take up iron, but I cannot give you some of these more readily than by reading a few words from what W. F. Durfee, of New York, has to say on the subject of "Wrought Iron." The article from which I quote appeared in the August number of the Iron Age and is a copy of a lecture delivered before the Franklin Institute a short time previously.

"The term 'wrought iron' is popularly supposed to designate a metal, but it is really the name of a mechanical admixture which, at its best, consists of clusters of crystals (which may with propriety be regarded as compound crystals) of practically pure iron, separated from one another, as the result of the manipulative processes employed, by films or threads of an unavoidable impurity called 'cinder.' * * * In the manufacture of wrought iron, the pig, or other variety of cast iron, is first deprived in a more or less imperfect degree, of its carbon and other impurities by what is known as the 'puddling process.' This process may be briefly described as consisting of four distinct operations, viz.:

"1. The melting of the pig iron.

"2. The boiling of the melted metal in a bath of liquid cinder (composed mainly of silicate of protoxide of iron) until the iron (which owing to its loss of carbon and other impurities can no longer remain fluid at the temperature employed) begins to solidify in the form of small granules or crystals, which can be seen moving amid the boiling cinder like white hot peas in a red hot soup. When the iron begins thus to granulate or crystallize, it is said to be 'coming to nature.'

"3. The collection, by the puddler, of these granules or crystals into distinct masses called 'balls' which may with propriety be regarded as white hot sponges of iron saturated with liquid cinder, which fills all their numerous accidental and irregular cavities.

"4. The squeezing or hammering of these balls while still at a welding heat, into more solid masses, which are called blooms. These contain much less cinder and other impurities than the balls, but are far from being uniform in structure; for when the balls are squeezed or hammered (this last operation is often called 'shingling') for the purpose of expelling the cinder and welding the granules or crystals of iron into a homogeneous mass, the attempt is never wholly successful; also as the metal cools the cinder quickly acquires a pasty consistency and flows with difficulty, and a large portion inclosed in the interior cavities of the ball is merely flattened or elongated. Hence, it will be seen that the bloom is composed of a compact mass of granules or crystals of iron separated from one another at numerous points by films, layers or strings of cinder of very irregular dimensions. * * * * When a properly heated bloom or other similarly constituted mass of wrought iron is subjected to the action of the hammer or rolls the contained cinder endeavors to escape from its entangled mechanical alliance with the crystals of the iron and in so doing each particle thereof is driven into some line of least resistance, which is always finally located in a plane at right angles to the direction of the force acting upon the metal. * * * The direct consequence of the elongation of its compound crystals, and the effort of the intervening cinder to escape in the direction of least resistance while the wrought iron bloom is being forged or rolled, as before described, is the establishment of that structural peculiarity in the resulting bar known as 'fibre' which is one of the most conspicuous features of wrought iron and one not found in any other variety of ferruginous materials. When certain of the films or threads of cinder in a bar of wrought iron are so large as to be distinctly visible on its surface to the unassisted eye, they are called 'sand seams' or 'cinder cracks.'

"* * * Steel is iron freed from mechanically mixed impurities, such as cinder, etc., by a melting process during which there is combined with it chemically a small percentage (not large enough to prevent the metal being forged or rolled) of other impurities, introduced for the purpose of modifying its strength, hardness, elasticity or ductility in such a way and degree as to adapt it to the particular use to which it is to be applied. In short, while wrought iron is iron having (as the unavoidable result of the methods employed in its manufacture) its impurities mechanically mixed therewith, steel is iron having (as the result of the adoption of appropriate manufacturing processes) its impurities chemically combined."

I have gone rather at length into this paper, because Mr. Durfee has put in a few words a great deal of food for reflection. Many people say that they prefer iron to steel even to this day on account of "fibre." If they would only look into the subject a little, they would find that "fibre" is nothing but cinder which cannot be a desirable constituent of a forging which must depend upon the soundness of its welds to hold it together. Mr. Durfee makes that very plain. What is wanted is a metal free from impurities so that molecular attraction can be depended upon to give it strength. Such metal is obtained by the process adopted in the manufacture of steel. In that process the metal is melted and the cinders float on top and are taken off, leaving a homogeneous mass underneath and the only impurities that are in it are what have been chemically combined in it for the purpose of increasing its strength or modifying its physical properties.

Having determined upon the erection of a modern forge, the Bethlehem Iron Company deemed it unadvisable to handle iron in connection with steel. It was not considered good policy to have the workmen handle indiscriminately two dissimilar metals which required entirely different treatment.

We will now consider the details of the methods of making steel forgings as finally adopted by the Bethlehem Iron Company and by means of illustrations I will endeavor to make plain to you the reasons for their adoption.

Fig. 158 shows a general view of the works taken from the south side; the whole plant is a little over a mile in length. This plant, as here shown, is composed of the following departments:

Construction and Repair Department.—Comprising pattern shop, foundry, blacksmith shop, machine shop, pipe shop and erecting shops. Besides the execution of usual repairs the greater part of the heavy machinery now in operation at the works, including rolling mills, 125-ton hammer, 7,000-ton and 14,000-ton bending presses, and all structures for buildings, furnaces, girders, cranes, etc., have been produced in this department.

Blast Furnace Department.—Comprising eight furnaces in which high-grade, low-phosphorus ores are melted, mostly imported from Europe and mines owned by the company in the island of Cuba. The product is used in the manufacture of Bessemer steel for rolls, blooms and billets and also in the manufacture of open-hearth steel for miscellaneous forgings, armor plate, etc.

Puddling and Bar Mill Department.—Comprising eight puddling furnaces and five trains of rolls, the product of which is puddled bars and merchant iron and steel and light rails, fish plates, blooms, billets, slabs, angles and shapes.

Bessemer Steel Department.—Comprising eight iron and four spiegel cupolas and four 7-ton Bessemer converters, together with

FIG. 158. A GENERAL VIEW OF THE BETHLEHEM IRON CO. WORKS.

two blooming mills, two rail mills and two hammers; the product from this department amounts to over 300,000 tons annually, consisting of ingots, blooms, rails and billets.

Open Hearth Steel Plate Mill.—Recently finished, in which plates up to 126 inches wide can be rolled. This department has four open hearth furnaces of fifty tons capacity each.

Open Hearth Steel and Forging Department.—Consists of four open-hearth furnaces from ten to fifty gross tons capacity; plant for the fluid compression of steel; hydraulic presses from 2,000 to 14,000 tons capacity; one hammer with falling weight of 125 tons; three hammers for making small forgings; three oil-tempering and annealing plants for guns, miscellaneous forgings and armor plate; one harveyizing plant, together with 46 gas producers, 44 heating furnaces, two machine shops, blacksmith shop and steel foundry. This is the department which we will consider at the present time. The product of this department comprises steel forgings of all descriptions, including parts for built-up guns, marine and stationary engine shafting, forged solid or hollow, and armor plate, and in a subsidiary department are complete facilities for the fabrication of modern built-up steel high-powered guns of the highest quality up to the largest size made. A proving ground at Reddington, Pennsylvania, within a few miles of the works, and accessible by rail, comprises three high-powered rifled cannon, one 6 inch, one 8 inch and one 10 inch calibre, together with substantial butts for mounting armor plate for ballistic testing; also two standard Le Boulangé Bréger Chronographs for determining velocities of projectiles.

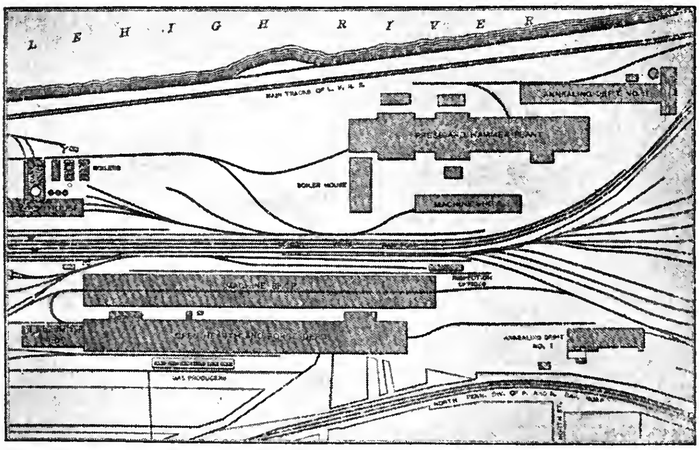


FIG. 159. PLAN OF FORGING DEPARTMENT.

The product of each department of the works is subject to inspection by inspectors engaged by the works, together with inspectors furnished by our own and foreign governments, and private and public corporations. The department of testing comprises a chemical laboratory fitted up in the most modern and im-

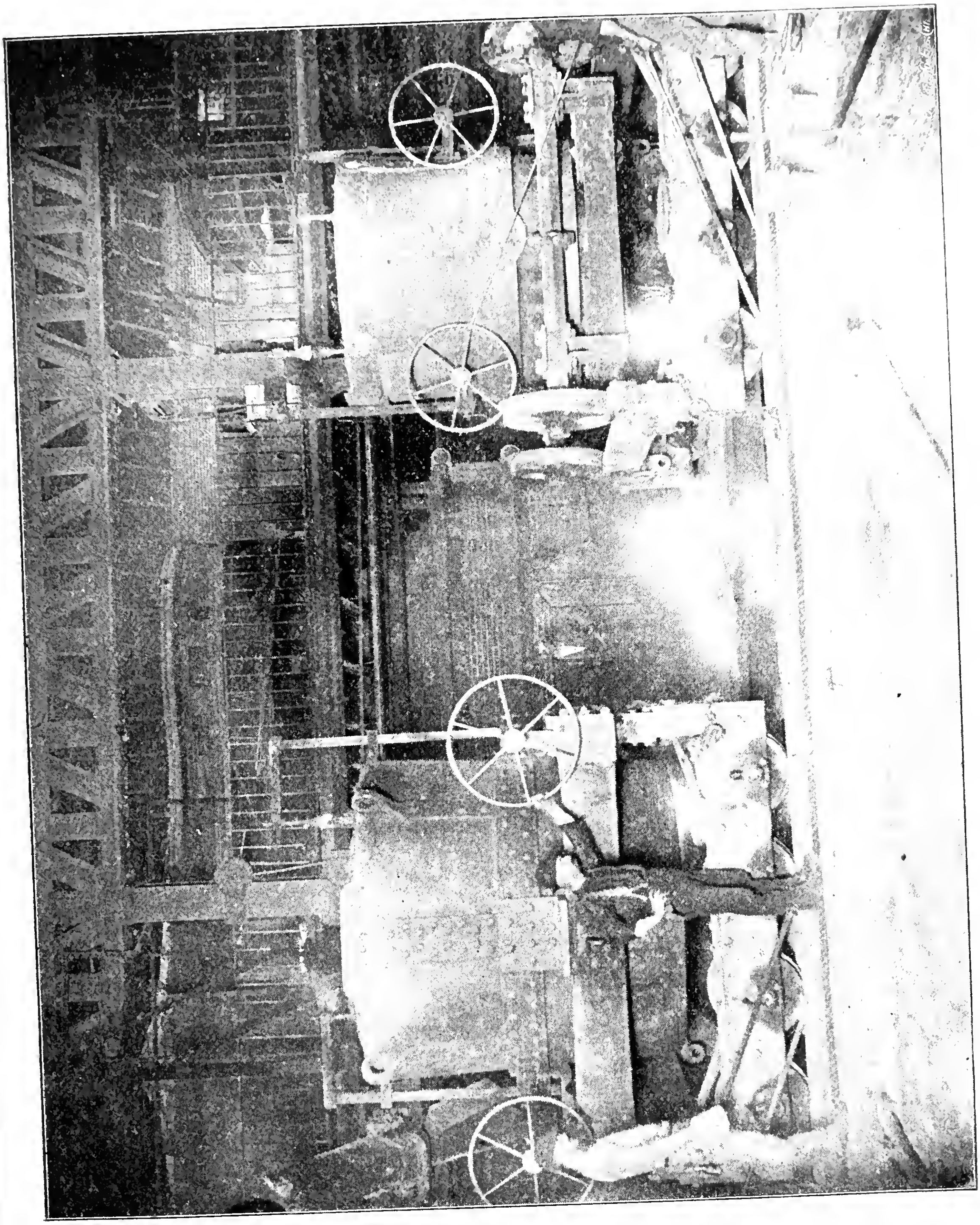


Fig. 160. Casting an Ingot.

proved manner for the rapid and accurate analyses of every variety of iron ore, iron and steel; a physical laboratory fitted with various machines for determining the physical qualtities of metals, including an "Emery Testing Machine" of similar construction to the United States government standard testing machine at the Wat-

ertown arsenal, with which constant comparisons are made to insure accuracy. Several other testing machines, all of standard make, are also in this department.

Fig. 159 shows a plan of the forging department only, the one that we will have under consideration this evening. One of the buildings has been added to since this picture was taken, and is now a little over 2,000 feet in length. Another building, constituting the machine shop, is within seventy-two feet of being a quarter of a mile in length.

Fig. 160 shows a small section of the furnace plant and represents the casting of an ingot. On an elevated shelf are located a series of open-hearth furnaces to which the various ingredients of the charge to be melted are raised on hydraulic lifts. In these furnaces (which are heated by gas generated extraneously) can be put such a composition of steel as will give the type of forging which is required for the service which it is to be subjected to eventually. Thus from ten (0.10) to fifteen hundredths (0.15) of 1 per cent. of carbon makes a grade of steel that differs but little in its strength from wrought iron, while an increase in its percentage up to a certain limit tends to make it stronger, and beyond that, hard and brittle. Too much phosphorus tends to make it brittle when cold, and sulphur to make it so brittle, when hot, that it can not be forged properly. High grades of steel should not have more than .04 of 1 per cent. of these elements in it. Others of its chemical constituents affect it in similar and other ways. Their combination in proper proportions can be arrived at only from long experience in constant handling and by observing their subsequent effect on resultant forgings in actual service. The furnace capacity here is so great that ingots can be turned out which are almost unlimited in size. So far ingots have been cast up to 125 tons in weight and they have not been called upon to produce anything greater, although they have furnaces with a total capacity of over 300 tons. From time to time, during the process of melting, a small dipperful of the molten metal is taken out of the furnace and rapidly tested, to ascertain how the refining is taking place, and when the charge is ready the metal is poured from the furnaces into ladles which in turn empty into moulds located in the casting pit underneath.

Fig. 161 shows an end view of this pit. Here is a mould in which steel is supposed to have been poured from the ladles shown in the previous picture. Moulds of this character are from one to six feet in diameter and are built up in sections to any desired height.

In order to make a forging properly, the best practice requires that an ingot be cast twice its diameter, in order that sufficient work may be put into the original casting during the forging process to give the metal strength and toughness. Besides this increase in diameter there is added thirty to fifty per cent, to its length for reasons which I will try to make apparent to you.

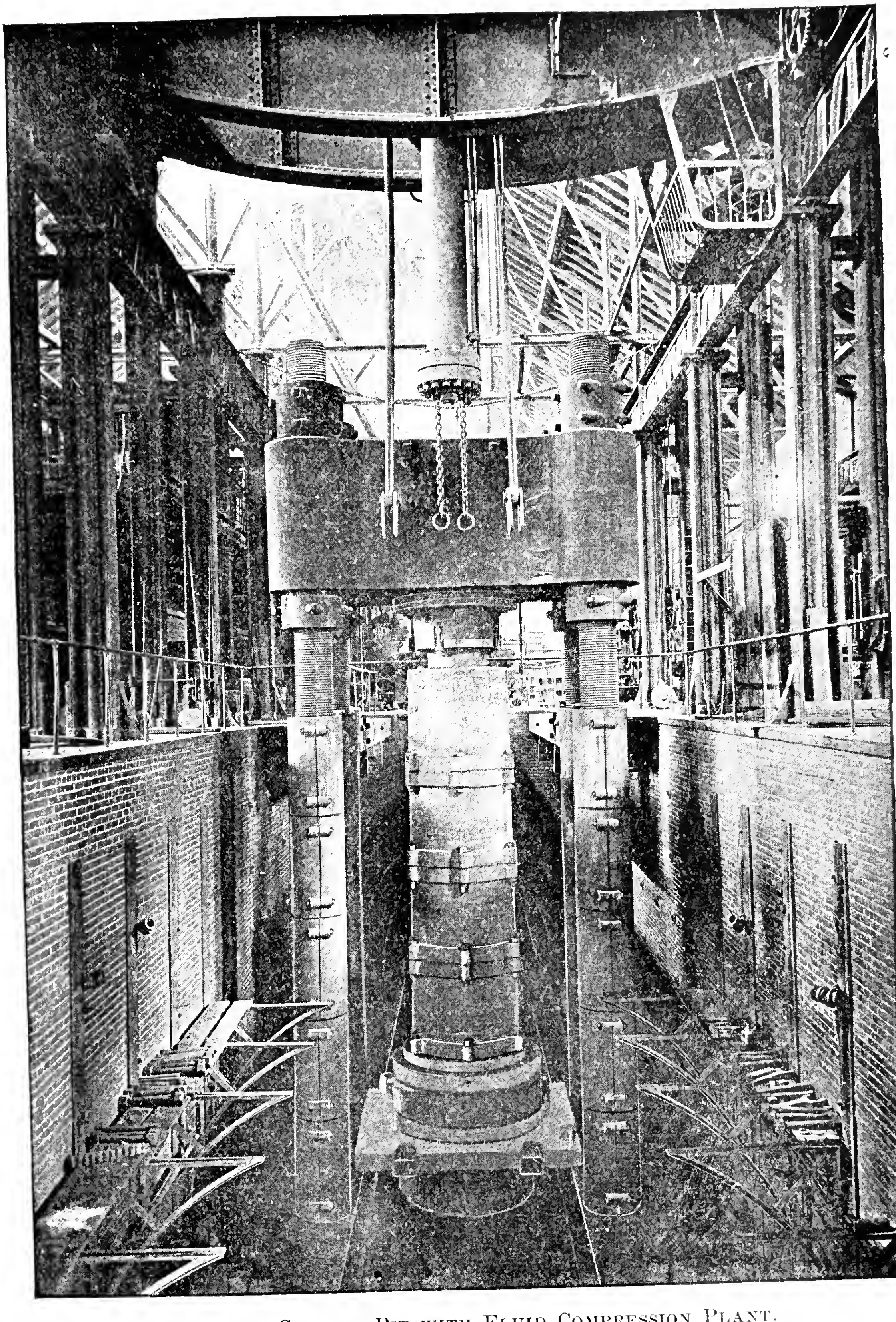


FIG. 161. CASTING PIT WITH FLUID COMPRESSION PLANT.

While the metal is being poured into the mould, there is a possibility of air being entrained in the liquid mass and subsequently gases are often generated during the cooling of the metal. From both of these causes "blow holes" are apt to be formed in the ingot. In order to overcome such defects the mould is placed on a platen and is slid underneath a hydraulic press. The process which I am describing is known as the "Whitworth Process of Fluid Compression." This press has a capacity of 7,000 tons, and under that enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating.

Another defect which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the center and from the top, these being the parts that solidify last. There is, therefore, added to take care of this shrinkage from 30 to 50 per cent more metal to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this part, that has been added, down through the center and thus we are enabled to keep the latter filled where otherwise we would have cavities or "pipes."

Another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus, manganese, silicon, etc.), each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is toward the central and upper portion where the metal cools last, thus forming a central core of impurities. This does not occur to such a great extent in small ingots, but in all large ingots it does occur and even this process of "fluid compression" does not entirely prevent it. But it does succeed in giving us a perfectly solid and homogeneous piece of steel, with the exception of "segregation" in large ingots, and that defect I will show later can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and if we have any defects in the ingot to start with, they can not be remedied later by hammering, as might be the case if we were dealing with iron, which possesses the property of welding.

Fig. 162 shows a fluid compressed steel ingot after being taken from the mould. It is twice the diameter of the forging to be made from it, and has over thirty per cent. extra metal at its top to take care of "piping" and "segregation," as already mentioned. This extra length, having served its purpose of supplying metal to fill

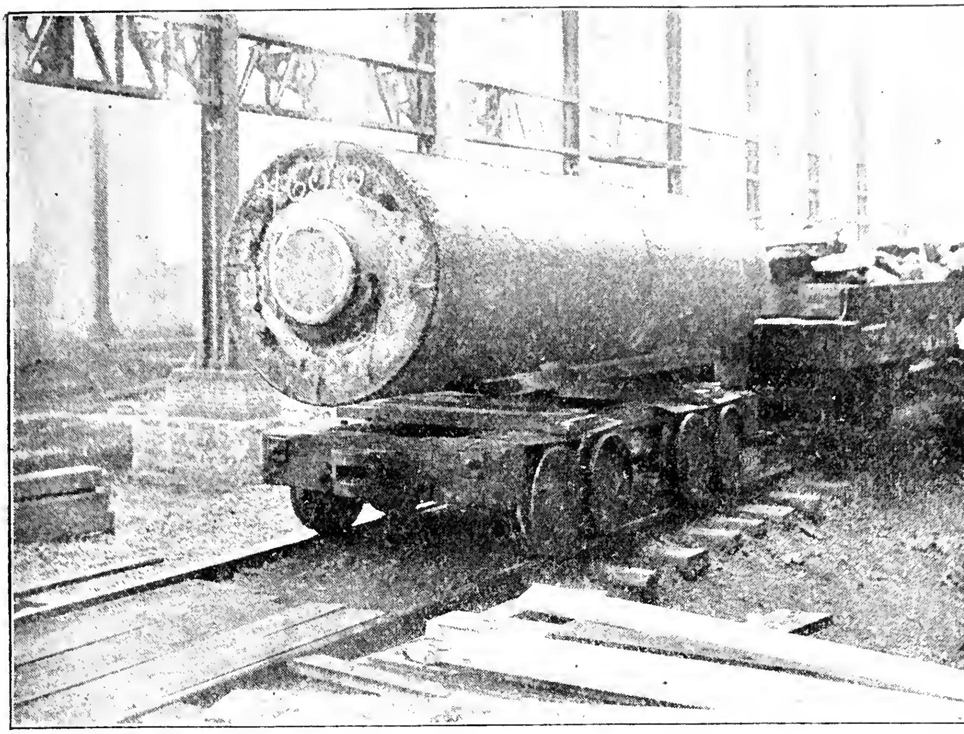


Fig. 162. An Ingot.

blow holes and pipes and of collecting segregation, is cut off and returned to scrap. The ingot is then ready for the forging process.

The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one. (Fig. 163.) Great care must be taken that the heat penetrate the metal slowly and uniformly.

As I have already told you, the metal in an ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain throughout its interior. Now, if we put a cold ingot into a furnace to be reheated, we immediately expand the surface metal and pull it still further from the center and thus put an additional strain on the metal inside. In very large ingots cracks are thus apt to be started in the center and forgings are very liable to break in subsequent service from the fact that they have not been properly re-heated. This process is not considered of sufficient importance by forges generally and a great many forgings fail from lack of care being taken at this time.

Now comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be sufficient in amount and of such a character as to penterate to the center and cause flowing throughout the mass. This flowing of the mental requires a certain amount of time and the requisite pressure should be maintained throughout a corresponding period. Fig. 164 shows the effect

of forging a large shaft under a light hammer. The blow is made very quickly, forced by top steam, so that the metal has not sufficient time to flow and all that has been accomplished is damage to the surface metal without any affect whatever being produced on the center. There is a tendency to draw the surface metal away from the center and you will find, on all large shafts which have been forged under light hammers, that well-known concave end which is shown in the diagram where the surface metal has been drawn away to such an extent as to leave cracks and sometimes large cavities in the center. What is shown at the end is simply an evidence of what has occurred all the way through the shaft. Now if we use a press in place of a hammer on the same-sized shaft, the pressure is applied very slowly, allowing time for the molecules of the metal to flow easily, and we then have the pressure passing all the way through the metal, and as the center is hotter than the surface, and therefore softer, it will be squeezed out and you will

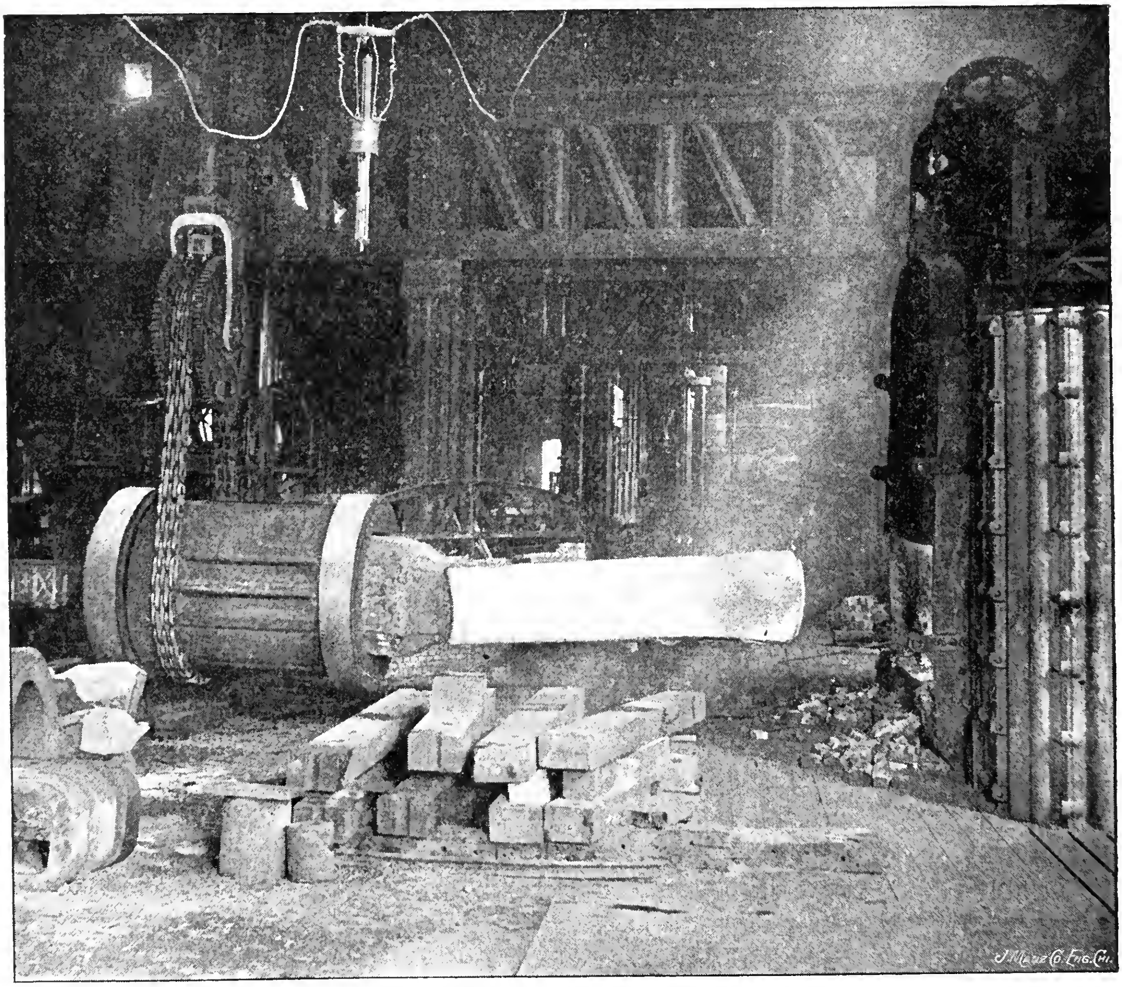


Fig. 163. Reheating of the Ingot.

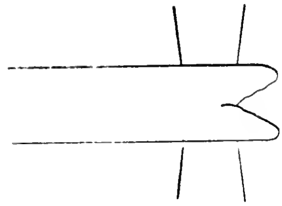


FIG. 164.

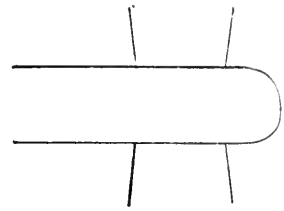


FIG. 165.

have the convex shape shown in Fig. 165 on the end of shafts that have been hydraulic forged. By the press only can large shafts be obtained without having defects formed in them during the process of forging.

Authorities on machine design have told us that "for wrought iron a safe strain per square inch should not exceed 9,000 pounds, and when the shafts are more than ten inches in diameter, 8,000 pounds. Steel, when made from the ingot and of good material, will admit of a stress of 12,000 pounds for small shafts, and 10,000 pounds for those above ten inches in diameter. The difference in the allowance between large and small shafts is to compensate for the defective material observable in the heart of large shafting owing to the hammering failing to affect it." I quote from Kent's Mechanical Engineer's Hand Book, and the authorities referred to are R. H. Thurston and the English engineers Seaton and Unwin.

Fig. 166 represents one of the hydraulic presses which is used in the place of a hammer. It is representative of various other presses of capacities from 2,000 up to 14,000 tons, whereas the heaviest hammer that I have seen in any of the forges in the west has not exceeded 25 tons with top steam.

Many so-called "steel forgings" are turned out by forges which have not sufficient capacity to make them properly. Instead of working them down from ingots twice their diameter, as best practice would require, they are compelled, because they have not hammers heavy enough to do the work, to use ingots which are only slightly in excess of the size of the finished forging. Such forgings are little better than steel castings and do not last long in service.

Fig. 167 represents the same ingot which I showed you in the previous picture, now being drawn out in the forging process. In this process of reduction in diameter and increase in length a great deal of work has been put into the metal. In order that the metal should be worked at the proper temperature it is necessary to reheat it a number of times, and every time that a blow is made by the press the metal has been worked under different conditions than when the preceding blow was made, because it has cooled a little in the interval. As, therefore, no two parts of the forging have been treated the same, it is natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been re-heated from time to time in different places, as the forging process passes from one end of the piece

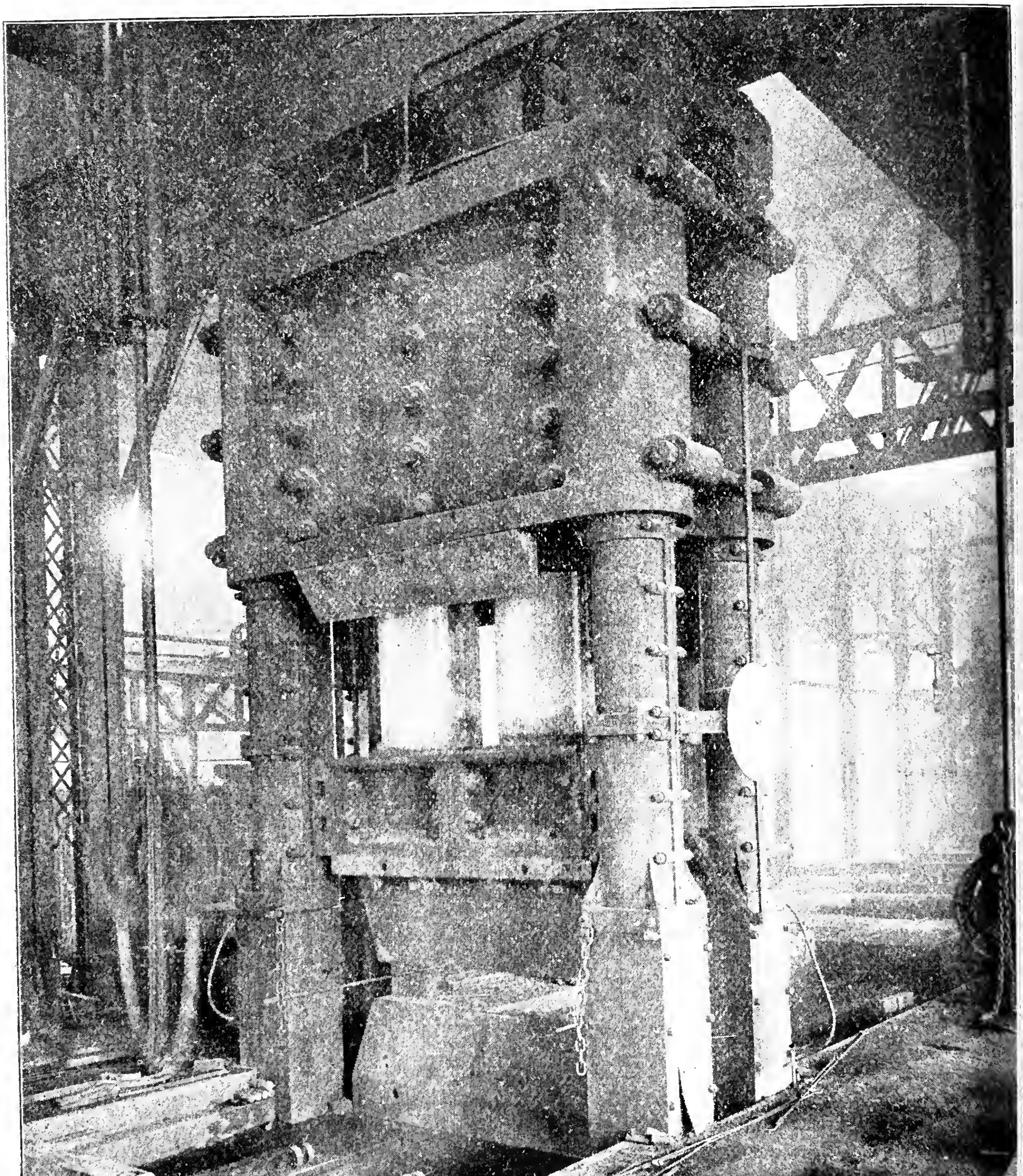


FIG. 166. HYDRAULIC PRESS

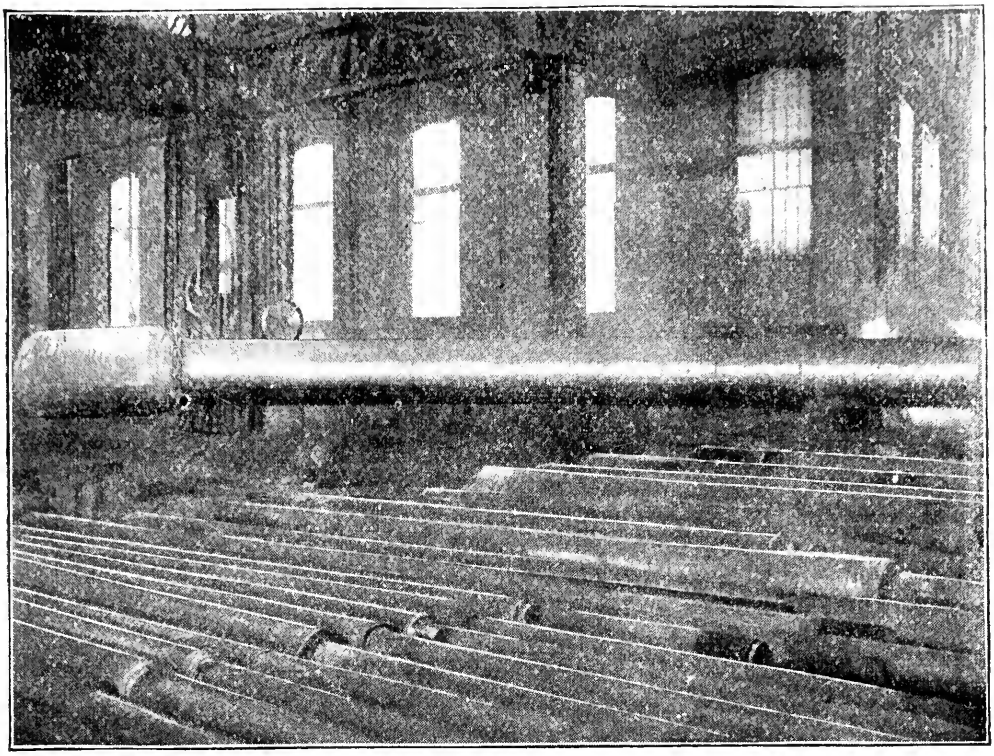


FIG. 167. INGOT IN PROCESS OF BEING FORGED.

to the other. To relieve these various strains all forgings are subjected to a final process called "annealing." This consists in putting the forging into a furnace, starting a wood fire around it, and heating it to a definite temperature which is decided upon by experience according to the service to which it will eventually be put, and then allowing the fire to die out and the furnace and forging to cool down slowly together. An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased very considerably, as shown by its contraction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods which is from two to ten thousand pounds lower. All forgings should be annealed and all specifications should be drawn that way. It is a process which is very seldom gone through with in forges because it is not required in specifications and no one can tell whether a forging is annealed or not until after it has been in service for some time, when the forging and cooling strains develop and throw the forging out of shape.

Figs. 168, 169 and 170 show representative solid forgings of various sizes and shapes.

Tests made on connecting rods furnished to the Edward P. Allis Co. show the quality of steel recommended for work of the character shown in Fig. 13, as follows:

Chemical Analysis:	Carbon	.20
	Manganese	.51
	Phosphorus	.036
	Sulphur	.027
	Silicon	.092

Physical Tests	Tensile Strength	62,390 lbs.
	Elastic Limit	34,490 lbs.
	Extension	29.25 per cent.
	Contraction of Area	52.01 per cent.
	Fracture	Irregular grey.

In order to obtain from steel the very highest results there are processes to which it should be subjected after forging which will develop its physical properties. One of these is that of "tempering." Fig. 171 shows the tempering plant. The forging is first re-heated to a definite temperature in a vertical gas furnace, then taken out and dropped suddenly into a bath of cold liquid which may be composed of oil or any similar non-conductor. The shaft in the picture is over sixty feet in length and is shown hanging from a traveling crane after having been withdrawn from the furnace, and is about to be dropped into the cold bath shown in the foreground. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition, existing after forging, is broken up and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionally to the tensile strength and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces. In order to successfully temper a piece of steel great care must be taken, both in the process of reheating it and also in cooling it in the bath. In re-heating it the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained; and in dropping it into the cold bath the surface metal is apt to contract onto the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging it should be hollow. By taking out the center it can be re-heated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and exterior together. Also, in dropping it into the cold bath there is no solid center on which the surface metal is contracted, and in that way the danger of cracking the surface during the cooling process is eliminated. There are two ways of making a forging hollow. The ordinary way of getting rid of the

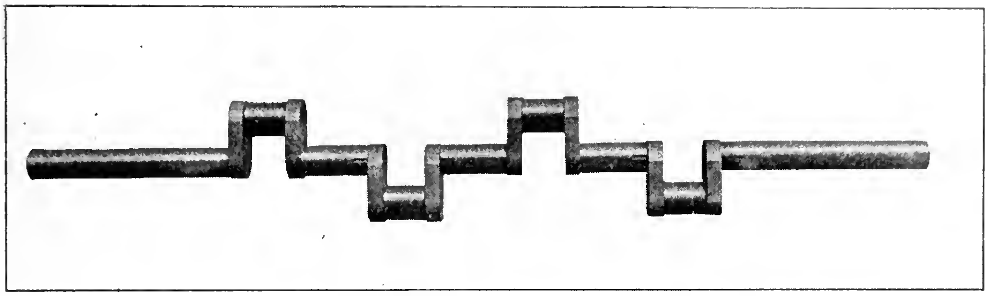


FIG. 168. Four-throw Crank Shaft for 100-horse power Gas Engine, manufactured by the J. I. Case Threshing Machine Company, of Racine, Wis. Diameter of shaft, $4\frac{1}{4}$ in.; diameter of pins, 5 in.; total length, 10 ft. $6\frac{5}{8}$in.; weight, 775 pounds.

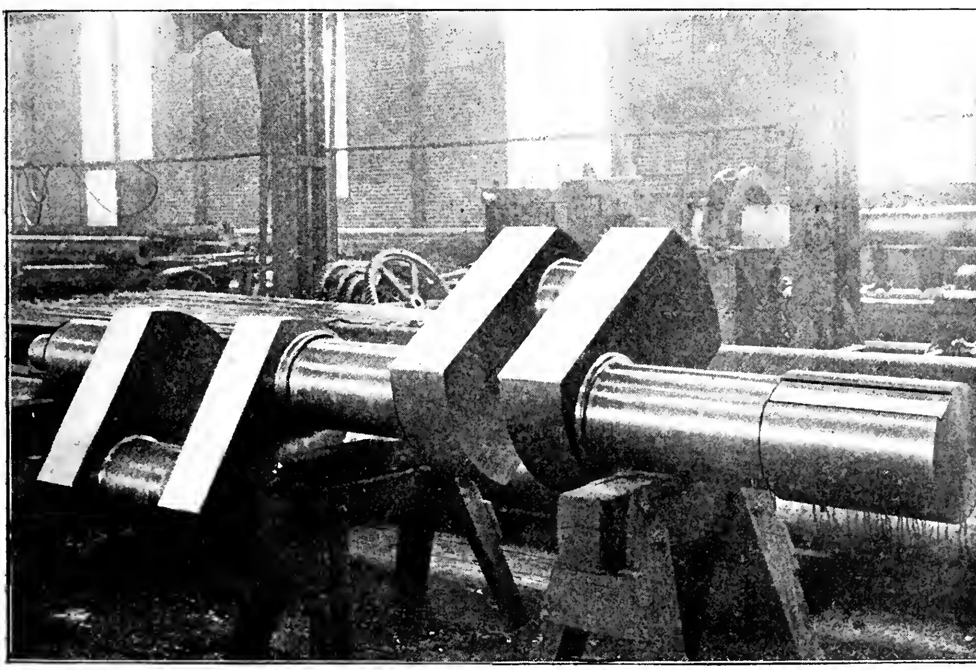


FIG. 169. Double-throw Crank Shaft for the De La Vergne Refrigerating Machine Company of New York, N. Y. Diameter of shaft and pins, 12 in.; total length, 13 ft. $1\frac{1}{8}$ in.; weight, 9,836 pounds.

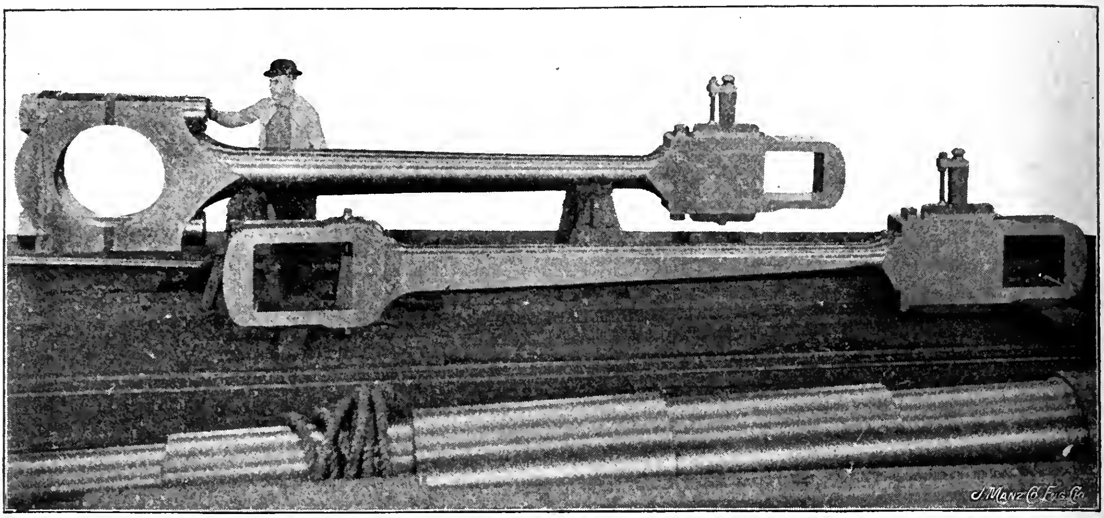


FIG. 170. Connecting Rods for 50 x 72 inches Reversing Engine for Jones & Laughlin; engine manufactured by Mackintosh, Hemphill & Co., of Pittsburg, Pa. Weight of small rod, 6,750 pounds; weight of large rod, 10,860 pounds.

center of a forging is simply to bore it out. After boring it is tempered and thus the strength is restored which was taken away with the metal which was in the center.

The hollow shafts which have been introduced into this country by Fried. Krupp of Germany have all been forged solid and bored and oil-tempered. The high grade of that kind of work is well known.

Figs. 172 and 173 represent hollow shafts of this bored type.

Another way of getting rid of the center of large forgings is to forge them hollow. A person who has not considered the subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already explained to you that there are various defects which occur in ingots, the most serious of which are "segregation" and "piping," and that it is in the center and upper portion where those defects occur. Now, if we were to make a hollow ingot, replacing the center by a solid core of fire brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and we would transfer the position of last cooling to an annular ring midway between these surfaces where we would collect the "piping" and the "segregation." This would not do, because the metal there is what we are going to depend upon for strength in our hollow forging. We, therefore, are compelled to make our forging solid as before, and collect our "piping" and "segregation" in the center and at the top, where we have added thirty to fifty per cent. to the original ingot for the purpose.

Then, having cut off the top and thus getting rid of what "piping" and "segregation" there are there, we bore out the center and so get

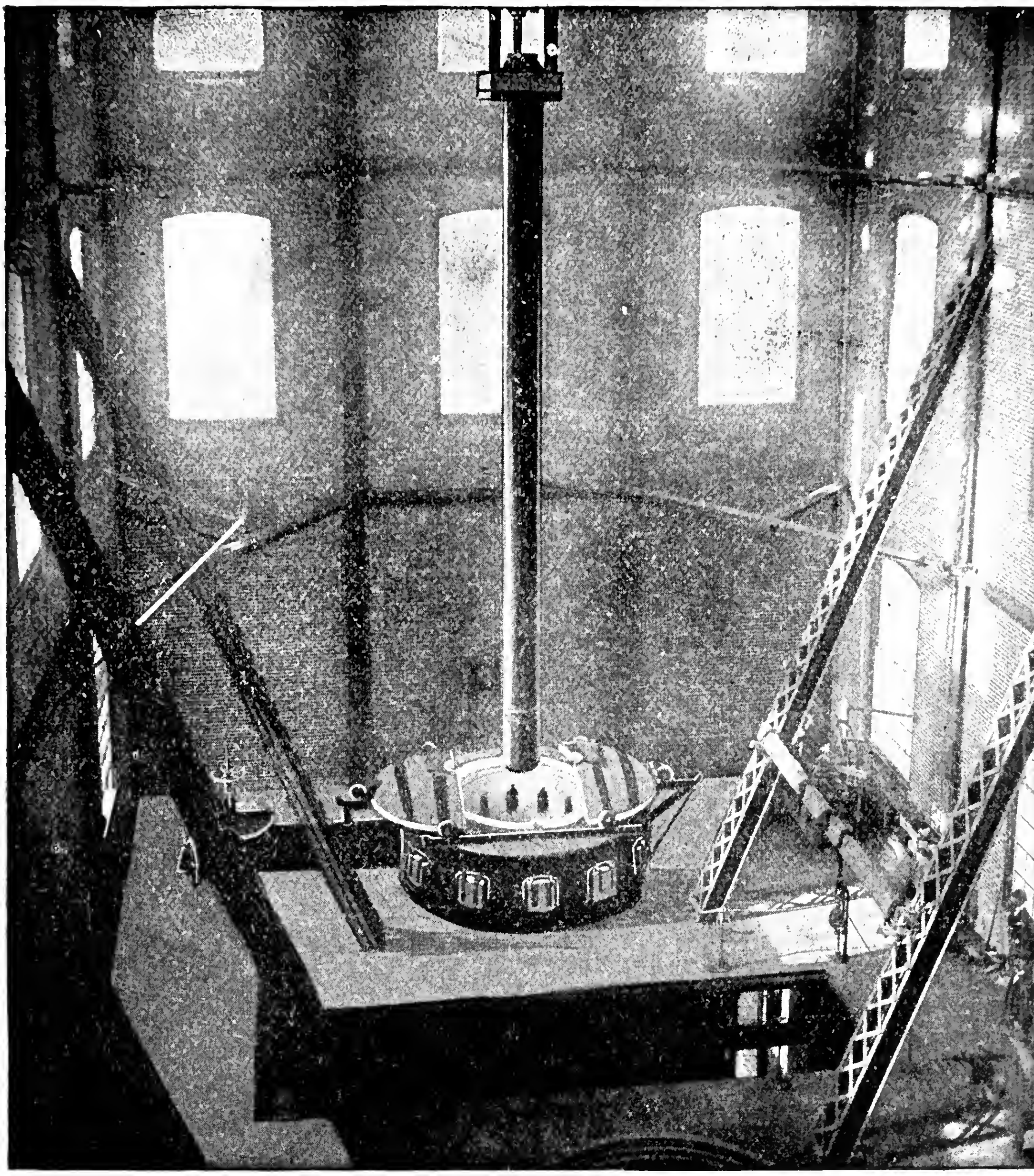


Fig. 171. Tempering Plant.

rid of the "piping" and "segregation" there, and what we have left is an absolutely sound and homogeneous piece of steel. (Fig. 174.)

After the hole has been bored in the ingot, the next process is to re-heat it, and as before explained, as the center is taken out this process is not as delicate a one as if the ingot was solid. The heat affects the center of the ingot equally with the exterior and the two expand together and we thus do not incur the danger of cracking. When the ingot is re-heated we put a steel mandrel through its hollow center, and subjecting the two to hydraulic pressure, we force the metal down and out over the mandrel. (Fig. 175.) We thus

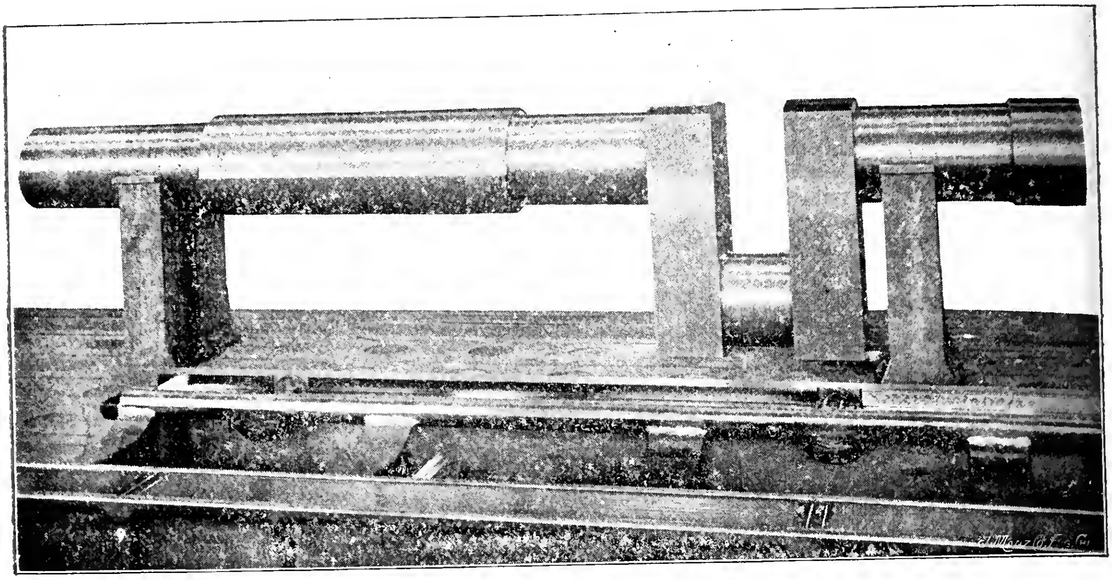


FIG. 172. Crank Shaft for a 50 x 72-inch Reversing Engine for Jones & Laughlin; engine built by Mackintosh, Hemphill & Co., of Pittsburg, Pa. Diameter of boss, $28\frac{3}{8}$ in.; diameter of bearings, 24 in.; diameter of pin, 23 in.; diameter of bore, 6 in.; throw, 36 in.; total length of shaft, 22 ft. 11 in.; weight, 47,950 pounds.

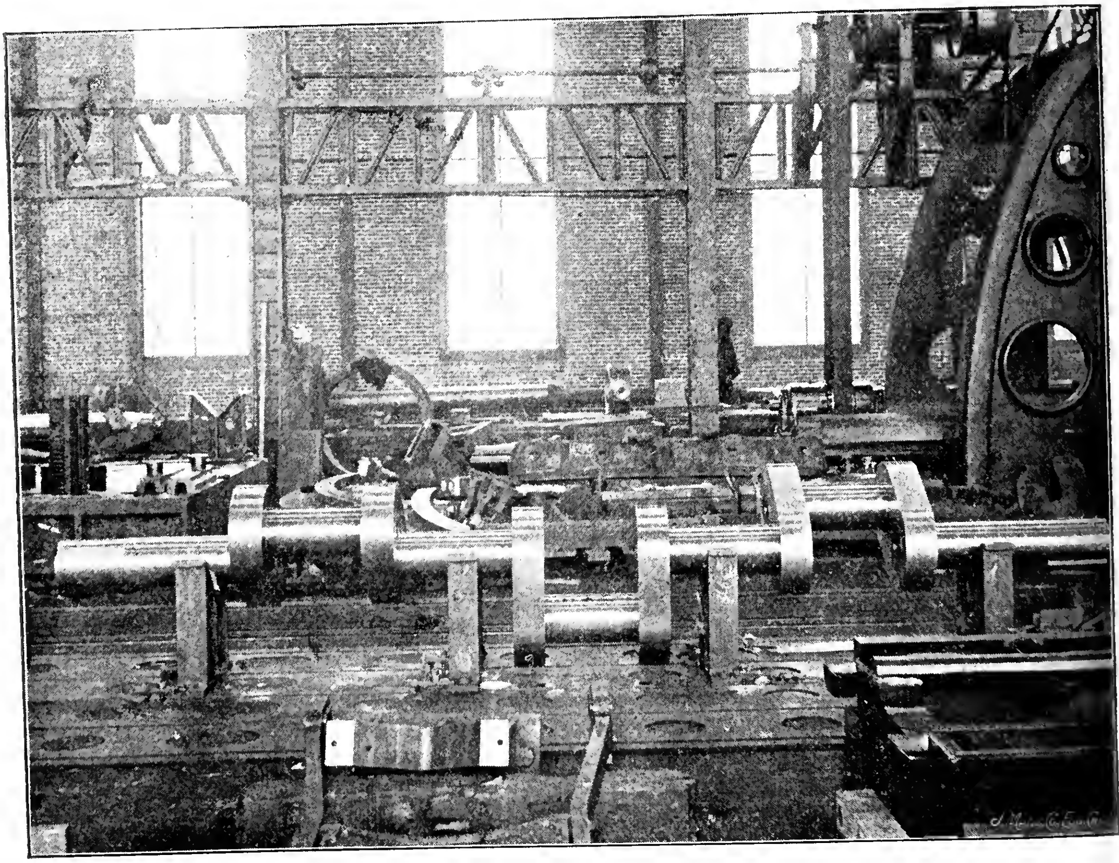


FIG. 173. Three-throw Built-up Crank Shaft for Pope Mfg. Company's Pumping Engine; engine built by Fraser & Chalmers Chicago, Ill. Diameter of shaft and pins, 11 in.; diameter of bore, 4 in.; total length, 19 ft. 11 in.; weight, 12,100 pounds.

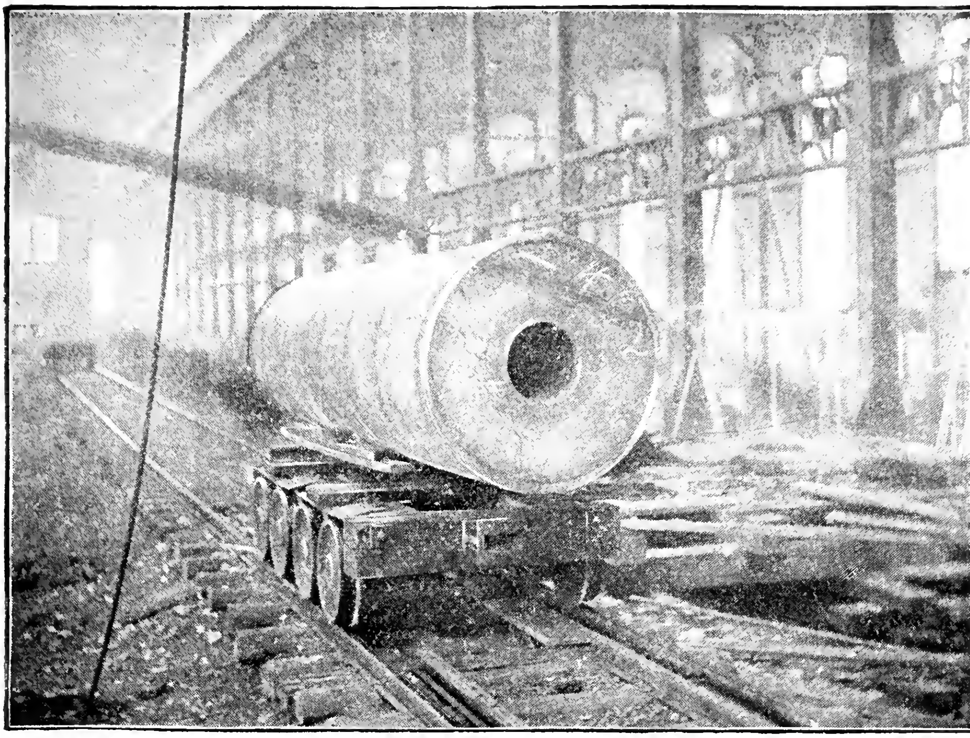


FIG. 174. BORED INGOT.

practically insert into the forging an internal anvil and we have therefore really much less than one-half the amount of metal to work on that we would have if the piece were solid. We have for instance, in the Ferris Wheel shaft (Fig. 176) 32 inches outside diameter, a 16-inch hole, which leaves only eight inches of metal to be worked upon between the press and the internal anvil. If we consider the restrictions which are placed on us by the authorities on machine design which I have mentioned, we would find that instead of being limited to 10,000 pounds for the fibre strain on a steel shaft which is more than ten inches in diameter, we would be allowed to run our fibre strain up to 12,000 pounds, because, although the exterior diameter of the shaft may be greater than 10 inches, still we are working on metal which is less than 10 inches thick, so that for large hollow shafts we are able to calculate a higher fibre strain, consider a lower safety factor, and in that way shafts which are hollow forged under this process are shown to be stronger than shafts which are of the same diameter and solid.

A large number of hollow forged shafts of this type have been made for engines in street and elevated railway power plants in Chicago under specifications drawn by S. Potis, chief engineer of the North and West Side roads, and R. J. Hill, chief engineer of South Side roads. These shafts have been about 28″ outside diameter, 11″ inside diameter, and twenty-five feet long. Similar shafts have also been made for pumping engines in municipal and mining plants throughout the country.

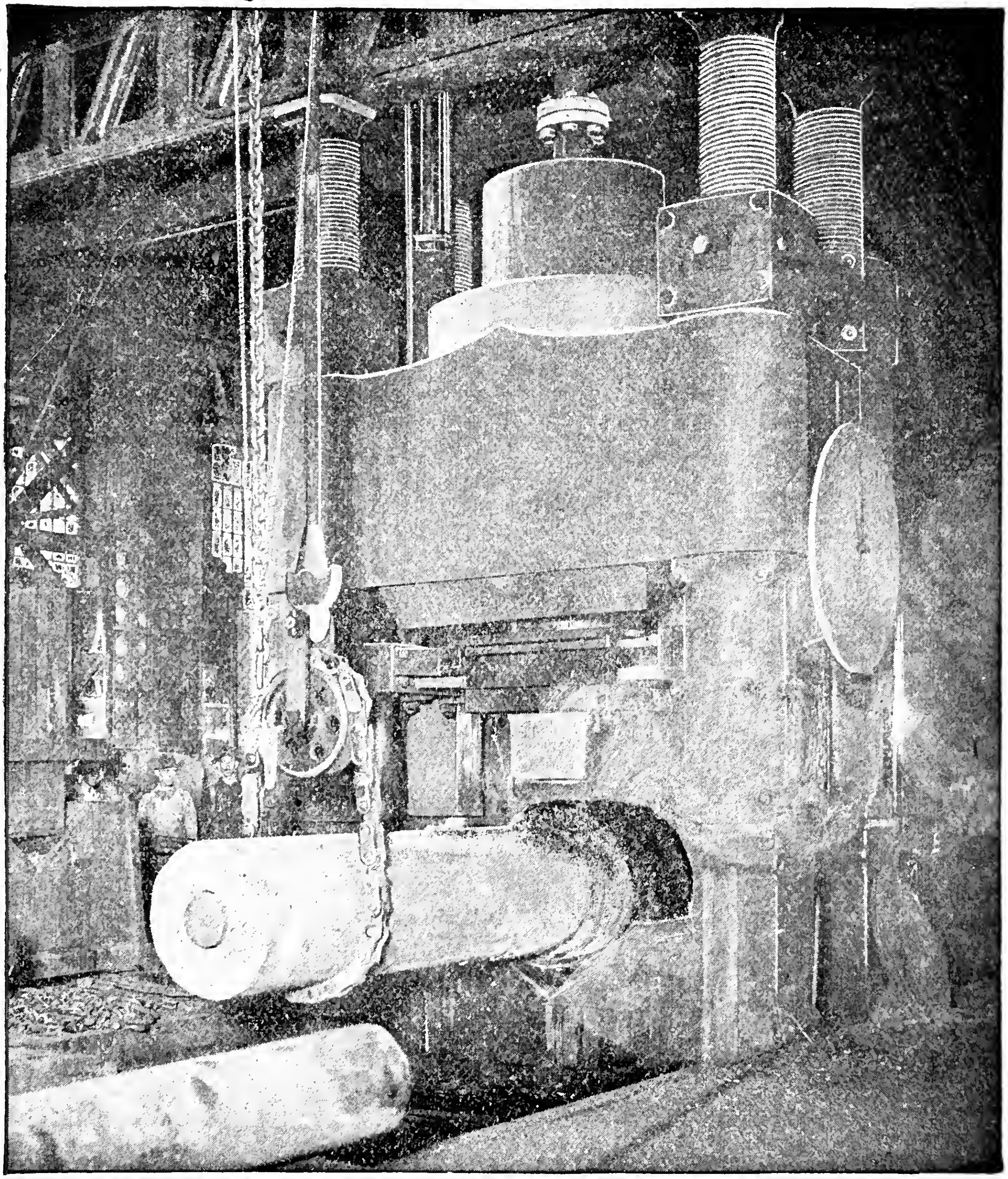


Fig. 175. Hollow Forging a Shaft Under 5,000-Ton Hydraulic Press

Fig. 177 shows the Yerkes telescope at the World's Fair. This picture was given to me not very long ago by Messrs. Warner & Swazey of Cleveland, who made the telescope and in whose space at the exposition it was exhibited. The two axes were hollow forgings, oil-tempered, 16 inches in diameter, with a four-inch hole in them. The moving machinery and time mechanism of the telescope are contained inside of them. A telescope tube was recently made for Warner & Swazey and Mr. Warner told me that he knew

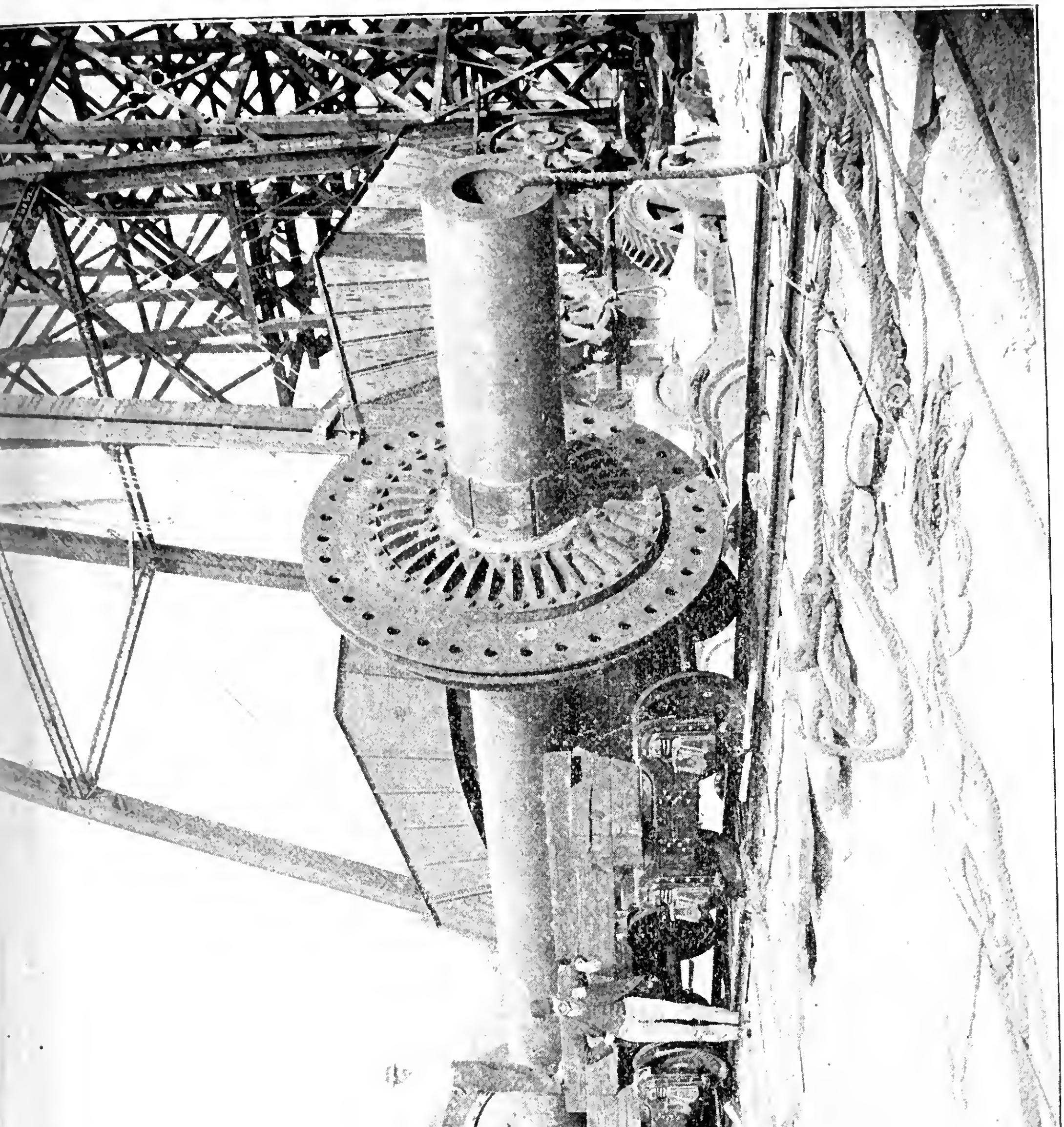


Fig. 176. Shaft for Ferris Wheel, 32 in. outside diameter; 16 in. inside diameter; total length. 45 ft. weight, 89,320 pounds.

the price would be pretty high for a hollow forged tube of this kind, which had to be very thin, for, inasmuch as the presses are very heavy, only large masses of metal can be properly handled under them. In fact it is not practicable to make hollow forgings whose walls are thinner than two inches. He decided, therefore, to try steel castings, and he bought twenty, one after the other, only to dis-

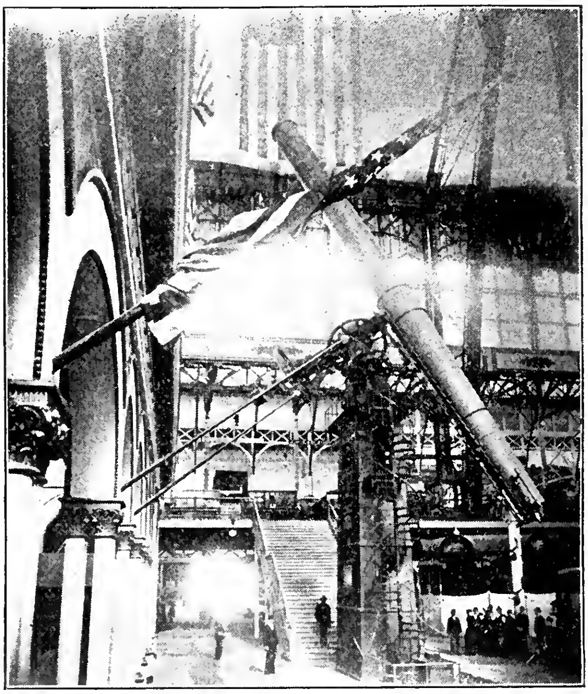


FIG. 177. Yerkes' Telescope. Hollow Axes. 16 in. outside diameter; 6 in. inside diameter, with flange at end $24\frac{9}{10}$ in. diameter.

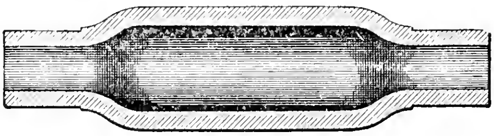


FIG. 178. A Shaft or Roll designed on the principle of a girder.

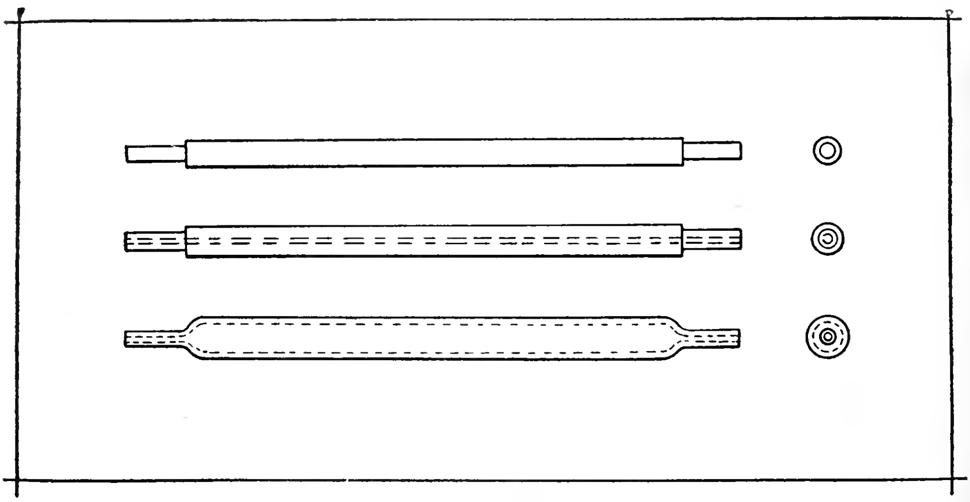


FIG. 179.

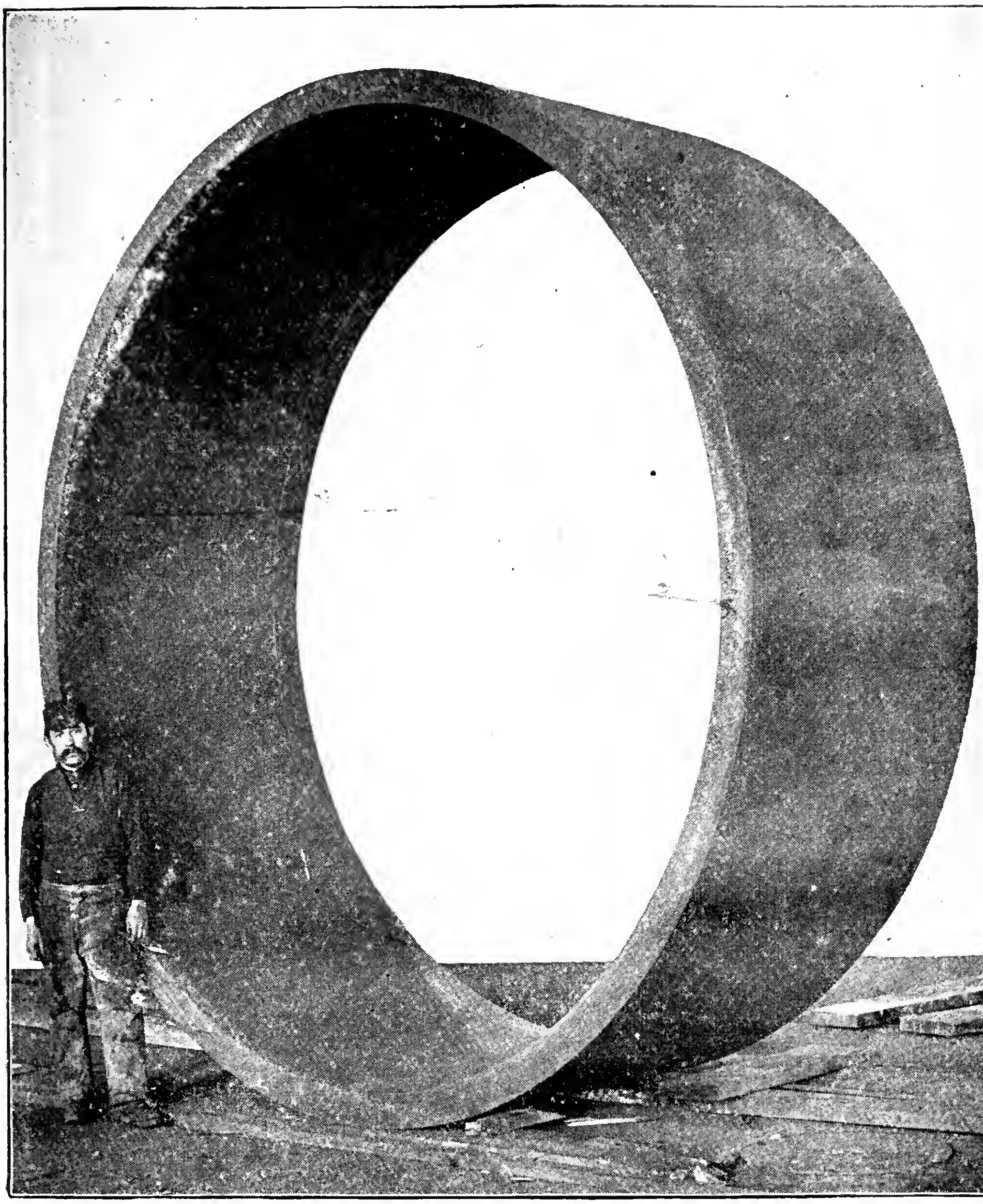


FIG. 180. Nickel Steel Field Ring, forged without a weld for 5,000 H.-P. Westinghouse Generator at Niagara Falls, N. Y. Outside diameter, 11 ft. $7\frac{3}{8}$ in ; width, 4 ft. $2\frac{3}{4}$ in.; thickness, $4\frac{11}{16}$ in.; weight, 28,840 pounds; tensile strength, 83,000 pounds; elastic limit, 53,000 pounds; elongation, 27 per cent.

cover blow holes in them after turning them down. Finally he gave them up in disgust and went to the Bethlehem Iron Company and got his tubing, which was made by hollow forging. After boring it out to the required diameter inside, a mandrel of the proper size to fit was put in and then the metal outside was turned off. When the pieces were finished they were 1-10 of an inch in thickness and were accepted as absolutely free from flaws and defects of any kind.

Undoubtedly the best type of hollow forged shafts, and one which is gradually being introduced, is where the walls are of the same thickness throughout, the outside and inside diameter varying together, both being greatest at the center where most strength is required, and smallest at the journals. (Fig. 178.) Such a shaft is designed on the principle of a girder and offers the greatest strength for the least amount of metal. Rolls for plate mills, made after this design, are especially desirable. This type of shaft is being introduced in stern wheel steamers on the Mississippi and Ohio Rivers.

The upper sketch in Fig. 179 shows the type of shaft which is now used on these steamers. It varies from thirty to forty feet in length and is only from twelve to fourteen inches in diameter. It is generally made of wrought iron. In the center is suspended a very large paddle wheel and the blow of the paddle on the water makes this center vibrate from an inch and one-half to two inches. This vibration eventually breaks the shaft. Somewhere on this wrought iron shaft there has been a poor weld, or a part of it is not as strong as the rest, and it breaks there. The shaft shown underneath is the type that has been furnished by Krupp of Germany for some years. We have also furnished some of that type of shaft, but it does not seem to be satisfactory. It is of steel, has the same diameter as the other shaft, is forged solid, then bored and oil-tempered. This shaft breaks like the other; it is not stiff enough. The type of shaft which is now being introduced in place of these is shown below. The center has been expanded over a larger mandrel, so as to make that part stiffer. It has the same weight as the first shaft, but is much stronger. Let me give you some comparative figures.

If we represent the strength of a solid wrought iron shaft, 14 inches in diameter, and 30 feet in length, as shown by the upper figure, by the figure 1, a solid shaft of steel of the same dimensions would be represented by the figures 1.29; if we were to make it of nickel steel, its strength would be represented by 2.6. Now, if we were to take the same shaft and simply bore it and anneal it, putting a $3\frac{1}{2}$-inch hole through it, its strength would be represented by 1, just the same as the upper shaft. If we subsequently oil-temper it, its strength would be 1.89. A hollow forged steel shaft of the same weight as the first, but of 22 inches outside diameter, with a 17-inch hole through it, would be represented by the figure 4; if oil-tempered, $5\frac{1}{2}$; if made of nickel steel, its strength would be represented by the figure 6; and if oil-tempered, by the figure 8.

Figs. 180 to 182 show hollow forgings of various types.

The tests made on the above forgings were all made on test pieces taken from full-sized prolongations which were forged on the end of each forging and treated in all respects like the forging. The United States Standard test piece, which is used in all of these tests, is one-half a square inch in section and four diameters in length. After recording tests of this character for a number of years and watching the service performed by forgings in actual use, it is possible to determine beforehand what the chemical composition of

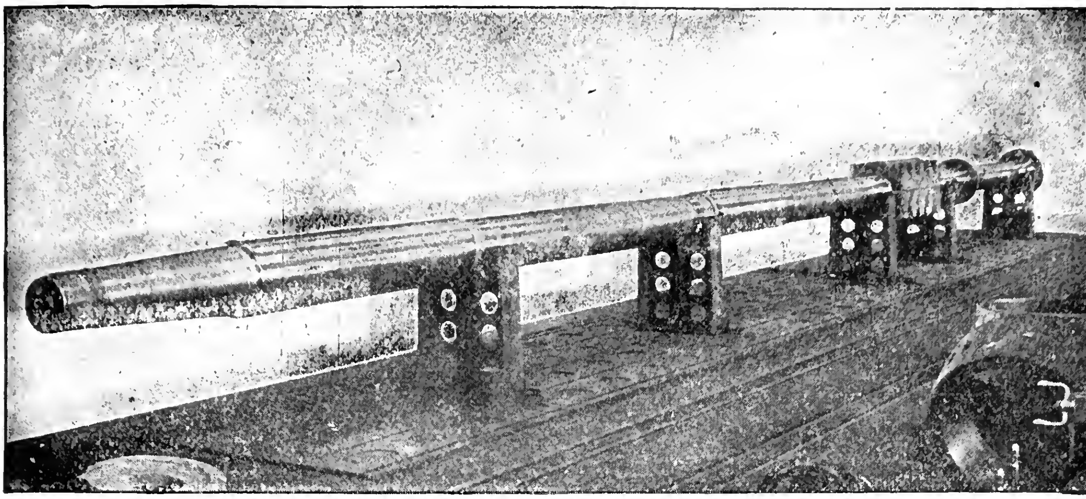


FIG. 181. Propeller Shaft for Ste.mers "St. Louis" and "St. Paul," of the International Steamship Co. Length, 53 ft. 5 in: outside diameter, 21 in.; inside diameter, 6 in.; hole plugged.

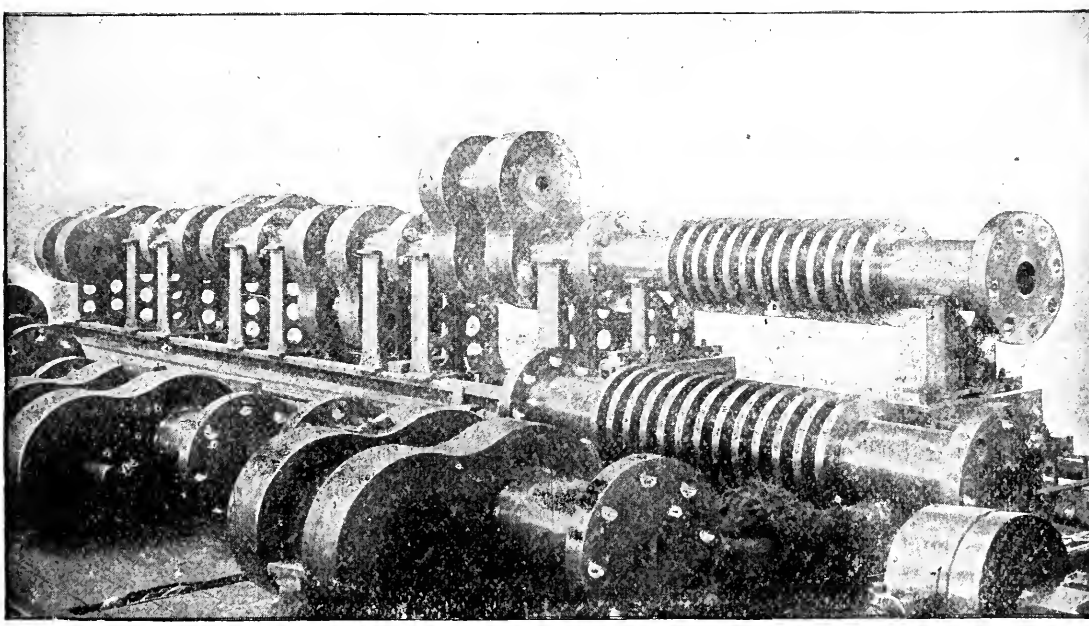


FIG. 182. Crank and Thrust Shafts for Steamers "St. Louis" and "St. Paul." Diameter of shaft, 21 in.; diameter of pins, 22 in.

steel should be in making up the charge in furnaces to produce certain forgings.

With the substitution in the trade of steel for wrought iron in engine and miscellaneous forgings, the tendency has naturally been to use a mild or soft steel approaching iron as regards physical qualities and in the ease with which it can be machined. Wrought iron has a low elastic limit, averaging about 20,000 pounds per square inch in large sections, where proper care is taken in its production.

Although mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity, and freedom from danger of imperfect welds and porous spots enclosing slag and scale, still it does not possess the very desirable quality of high elastic strength, combined with ductility or toughness, in as great a degree as can be obtained without danger in a harder steel, when proper precautions are taken in its manufacture. In other words, in the use of ordinary mild steel, only a partial advantage is taken of the most desirable qualities of steel which are easily within reach. In some instances where the amount of machine work in finishing is very great and there is ample margin of safety in the design, as, for instance, is often the case with connecting rods, the use of mild steel may be advisable. Such steel contains about .20 to .25 of one per cent. carbon, and can be guaranteed to show, in specimens four diameters in length cut from a full-sized prolongation of forgings or from representative pieces, a tensile strength of not less than 57,000 pounds per square inch, and an elastic limit of not less than 27,000 pounds per square inch, with an average elongation of 25 per cent.

For the general run of engine forgings, however, a harder steel should be used (in which a tensile strength of about 75,000 pounds and an elastic limit of 35,000 pounds per square inch can be obtained, together with an average elongation of 20 per cent. in four diameters.

When proper precautions are employed, forgings can be made with perfect safety of a still higher grade of steel, and this is especially recommended for crank and cross-head pins and for all parts subject to severe alternating strains and wearing action. In this grade of steel a tensile strength of about 85,000 pounds and an elastic limit of about 40,000 pounds per square inch can be obtained, with an elongation of 15 per cent. in four diameters.

If steel forgings are tempered they will possess still higher qualities than those above mentioned, and can be furnished with a tensile strength of 85,000 to 90,000 pounds and an elastic limit of 45,000 to 55,000 pounds per square inch, and an elongation of 15 to 20 per cent. in four diameters.

By introducing about 3 per cent. of nickel into the composition of steel, a finely granular or amorphous condition is obtained in forgings, and the very highest quality of steel is obtained.

By the combination of hollow forging and tempering this nickel steel a material is obtained excelling all others known in elastic strength and toughness.

Fluid-compressed steel of .40 to .45 of one per cent. carbon, and more especially nickel steel, oil-tempered, is markedly adapted for piston rods of rock drills, mining machines, and hydraulic presses, and for drop-hammer rods, stamp stems, cam shafts and similar pieces that are subjected to stress alternating between tension and compression, or of either kind, frequently repeated. By substituting steel of this grade, which would have an elastic limit of about 60,000 pounds per square inch, for wrought iron or mild steel, which is

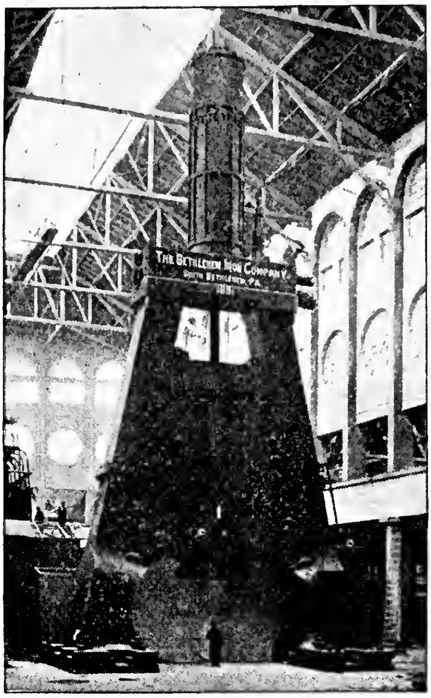


Fig. 183. 125-Ton Hammer.

generally used for the purpose, and by so proportioning the cross section that the metal is not strained beyond one-half the elastic limit, so-called "crystallization" from shock or vibration does not occur and their life is prolonged indefinitely.

The following pictures show some of the tools and forgings turned out by them, that are located in that part of the works where government work is performed.

Fig. 183 shows the model of the 125-ton hammer as it stood in the Transportation building at the late World's Fair. This hammer is no longer in use at the works, it having been replaced by a 14,000 ton press shown in Fig. 166. That the Bethlehem Iron Company had the courage of their conviction that the hammer was not the proper implement to use on steel is shown by the fact that after having built this, the largest hammer in the world, they laid it aside to use in its place the largest press in the world, run by a 15,000 horse-power pumping engine, which is in its turn also the largest of its kind in the world. In order that you may have some conception of the sizes of these tools, I will give you the following dimensions of parts of the hammer:

Anvil blocks, 2,150 tons.

Steam cylinders, 76 inches.

Stroke, 16 feet 4 inches; can be increased to 20 feet.

Steam pressure, 125 pounds.

Cylinder in three pieces—Top section, 15,449 pounds; middle section, 20,033 pounds; lower section, 21,005 pounds.

Entablature, $60\frac{1}{2}$ tons.

Legs in two sections, upper, $48\frac{1}{2}$ tons each; lower, 107 tons each.

Guides, $75\frac{1}{2}$ tons each.

Base plates, 10x8 feet thick, 56 tons each.

Total height, above floor, 90 feet.

Total width, 38 feet.

Fig. 184 gives an interior view of the machine shop in which miscellaneous forgings and guns are finished. This building is 1,246 feet long ($\frac{1}{4}$ mile, lacking 74 feet), 111 feet wide. This shop is supplied with power by four 200-horse-power engines, two on each side. It is served by two 75-ton pneumatic cranes and one of 30 tons capacity. It is furnished also with a large variety of machine tools of varying capacity, among which are some suitable for the heaviest class of work. There is a planing tool here which can finish a piece of metal 13 feet wide, 13 feet high, and 55 feet long, and a lathe capable of handling pieces 10 feet in diameter and 80 feet long.

Fig. 185 shows a large ingot for a side armor plate of the battleship "Maine." Weight, 122.2 tons.

Fig. 186 shows a hollow forged nickel steel shaft, oil-tempered, which we made for the United States battleship "Brooklyn." Outside diameter, $17\frac{1}{8}$ inches; inside diameter, 11 inches; length, 38 feet $11\frac{3}{8}$ inches; weight, 19,122 pounds.

Test bars cut from this shaft gave the following results, viz.:

Dimensions of Spec.	Tensile Strength.	Elastic Limit.	Elongation per cent.	Contraction per cent.	Fracture.
0.496x2″	94185	58995	26.4	60.83	Dense grey lipped
0.497x2″	94245	60770	25.55	60.58	Dense grey lipped
0.497x2″	93215	59740	25.8	61.33	Dense grey lipped
0.497x2″	93730	60770	25.8	59.81	Dense grey lipped
0.498x2″	92410	59550	28.0	60.74	Dense grey lipped
0.498x2″	90350	56470	28.0	60.74	Dense grey lipped

Professor Merriman is quoted in a paper read before the Society of Naval Architects and Marine Engineers in 1893 by R. W. Davenport, as estimating the strength of these shafts compared to solid shafts as follows, when strained to one-half their elastic limit:

1. Propeller shaft United States steamship "Brooklyn," nickel steel.

a. Horse power transmitted at 50 revolutions per minute, 15,780.

b. Load in pounds at middle of a span of 12 feet on two supports, 276,200.

2. Simple steel shaft, solid, 13 inches diameter (same weight as above).

a. Horse power transmitted under similar conditions, 5,130.

b. Load in pounds under similar conditions, 89,000. Comparative strength as 3 to 1.

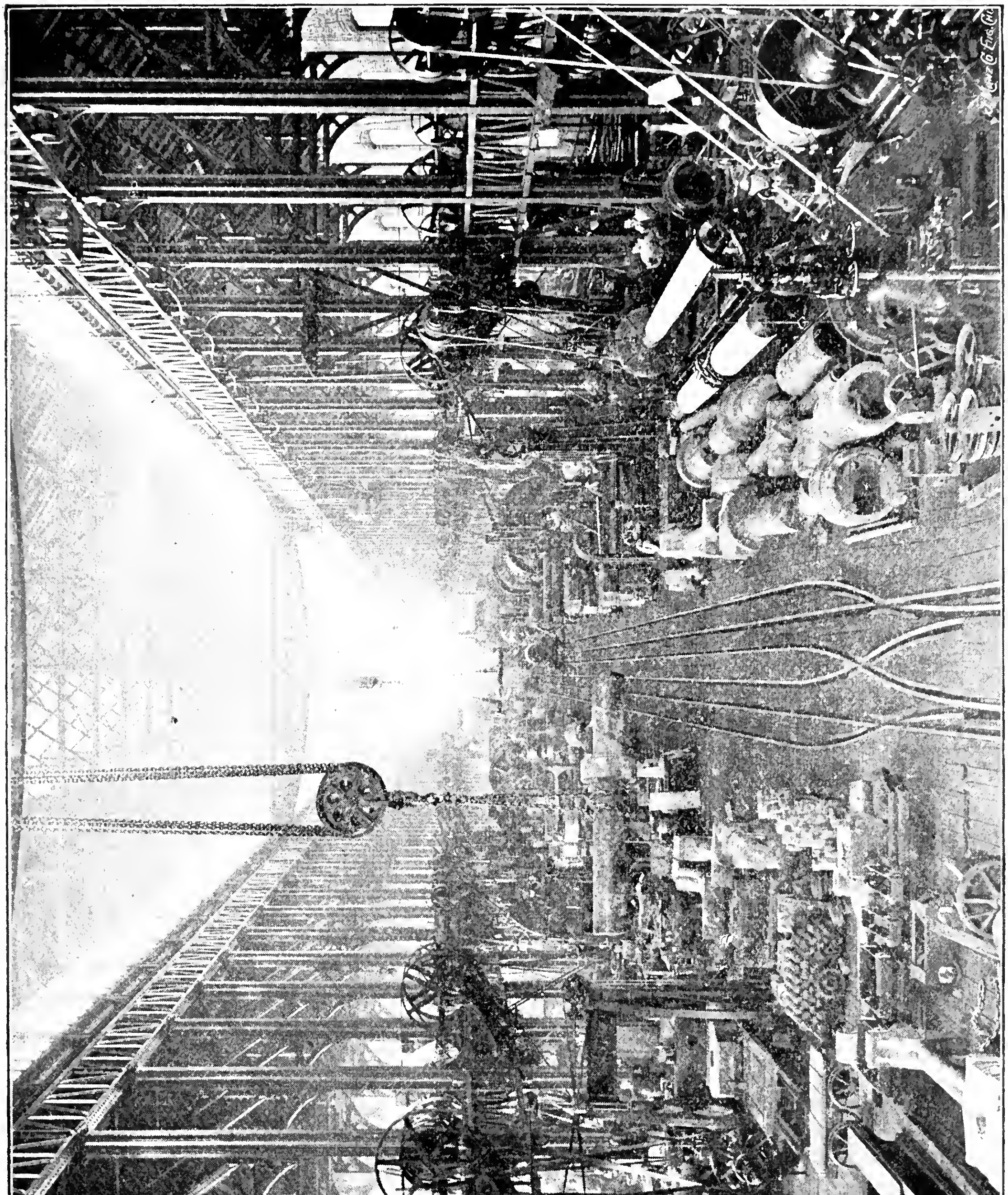


Fig. 184. Machine Shop No. 2.

3. A solid shaft of simple steel of the same strength as the hollow forged nickel steel shaft would be 18 9-10 inches diameter and weigh 53 per cent. more.

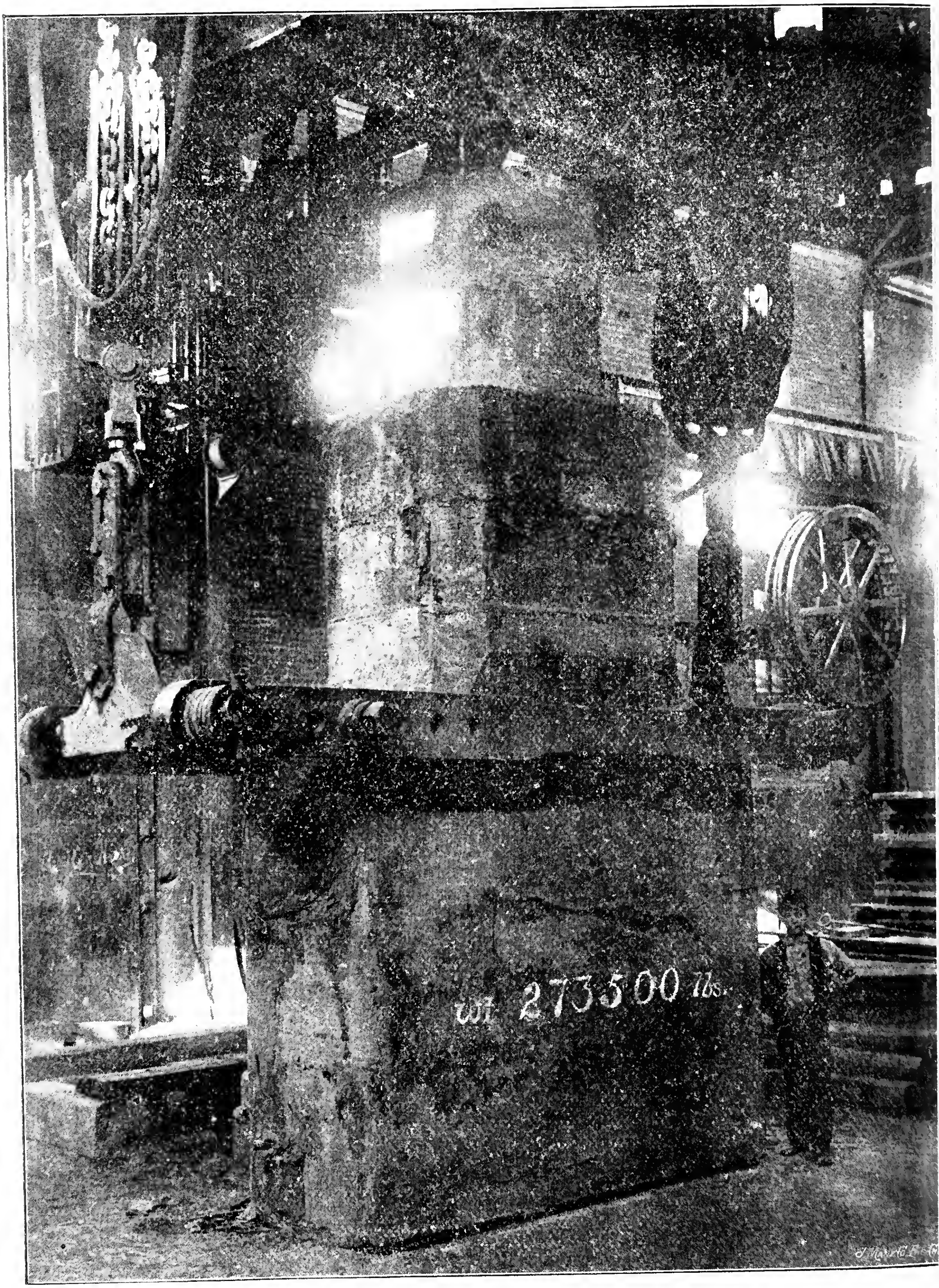


FIG. 185. AN ARMOR PLATE INGOT.

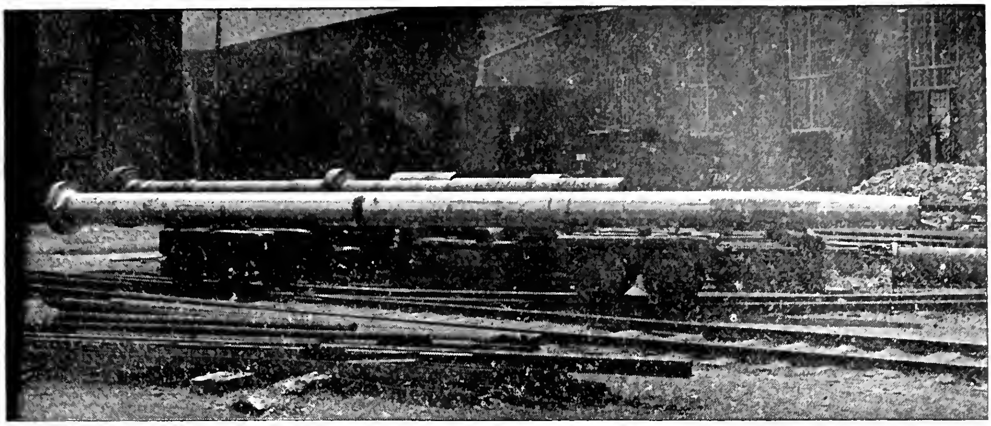


Fig. 186 Nickel Steel Propeller Shaft for U. S. Battle Ship "Brooklyn." Outside diameter, $17\frac{1}{8}$ in.; inside diameter, 11 in.; length, 38 ft. $11\frac{3}{8}$ in.; weight, 19,112 pounds.

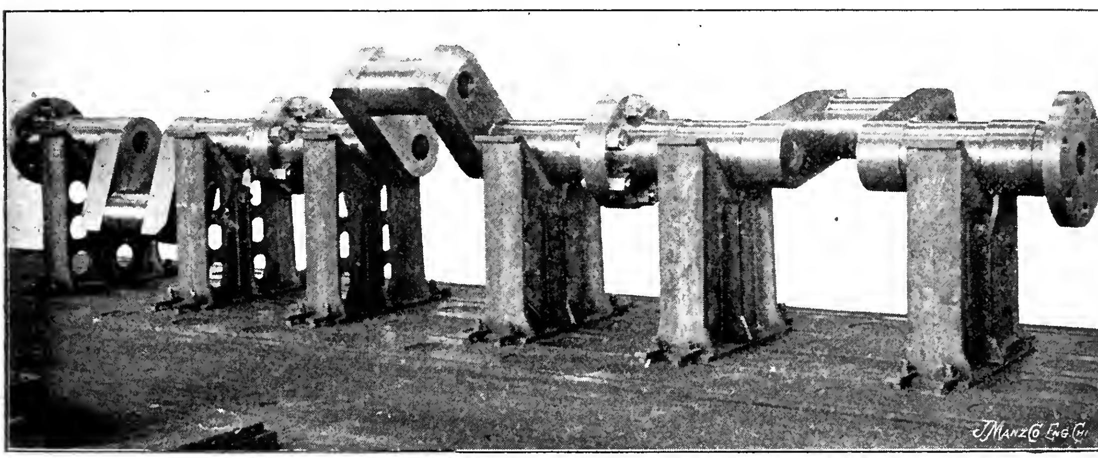


Fig. 187. Three-throw Interchangeable Crank Shaft for U. S. Battle Ship "Iowa." Length of each section, 9 ft. 6 in.; outside diameter of pin and shaft, 16 in.; hole, $7\frac{1}{2}$ in.; w ight, 8,600 pounds.

Fig. 187 shows three-throw crank shaft of the battleship "Iowa." This is what is known as the interchangeable type of shaft, where the three sections are made as nearly as possible duplicates of each other. A spare duplicate is carried in the boat and if an accident occurs to any section it can be replaced by the spare piece.

Fig. 188 shows the conning tower of the battleship "Brooklyn." It is made of nickel steel. This view shows very plainly the effect of forging with a press, the ends showing the bulging of the metal, which has been squeezed out from between the internal mandrel and the press.

Fig. 189 represents a 10-inch B. L. rifle, 35-calibre; total length, 30 feet $7\frac{1}{4}$ inches; weight, 67,365 pounds. This gun is built up. It is composed of an internal tube on which have been shrunk several

FIG. 188. Conning Tower for U. S. Battle Ship "Brooklyn." Outside diameter. 7 ft. 9¾ in.; inside diameter, 6 ft. 4½ in.; thickness, 8⅝ in.; length, 9 ft. 11 in.

jackets, each of which as well as the tube is a hollow forging.

Fig. 190 shows a barbette of the battleship "Indiana," with one plate removed to show the bolts which are used to fasten the plates to the backing.

In order that you may appreciate the toughness which can be given to a steel plate by proper treatment, I will show you the tests made on 14½-inch nickel steel hard-faced side armor plate for the Russian battleship "Sebastopol," Fig. 191. These tests were made at Ochta, in Russia.

Impact No. 1. 9-inch projectile, weighing 403.16 lbs.; striking velocity, 1870 f. s.; striking energy, 9785.1 ft. tons. Penetration undetermined, projectile broke up.

Impact No. 2. 9-inch projectile, weighing 403.16 lbs.; striking

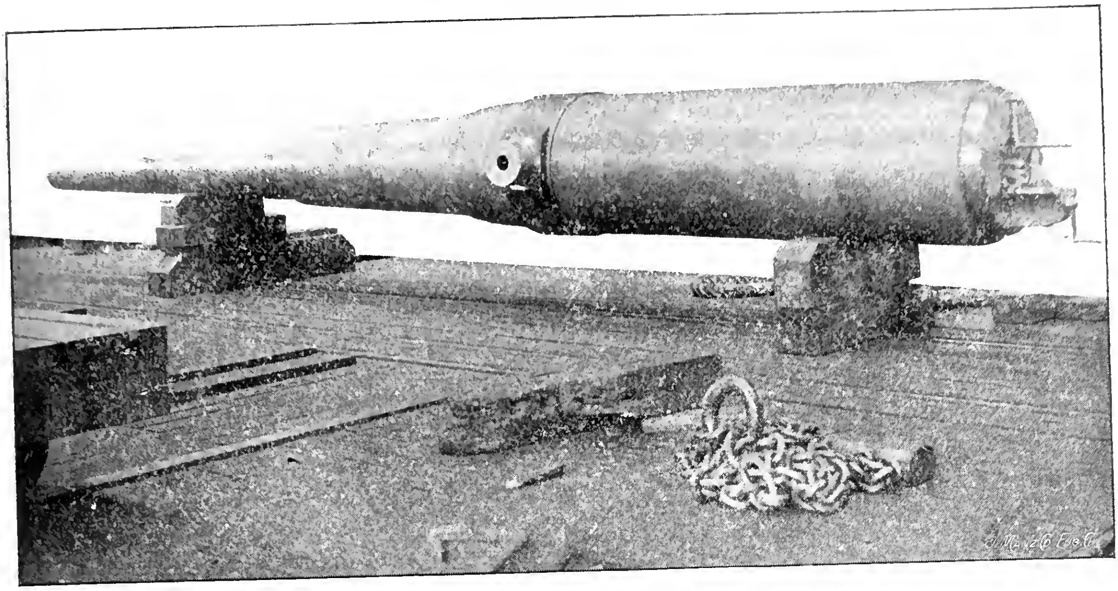


FIG. 189. Ten-inch Breech-Loading Rifle; total length, 30 ft. $7\frac{1}{4}$ in.; weight, 67,365 pounds.

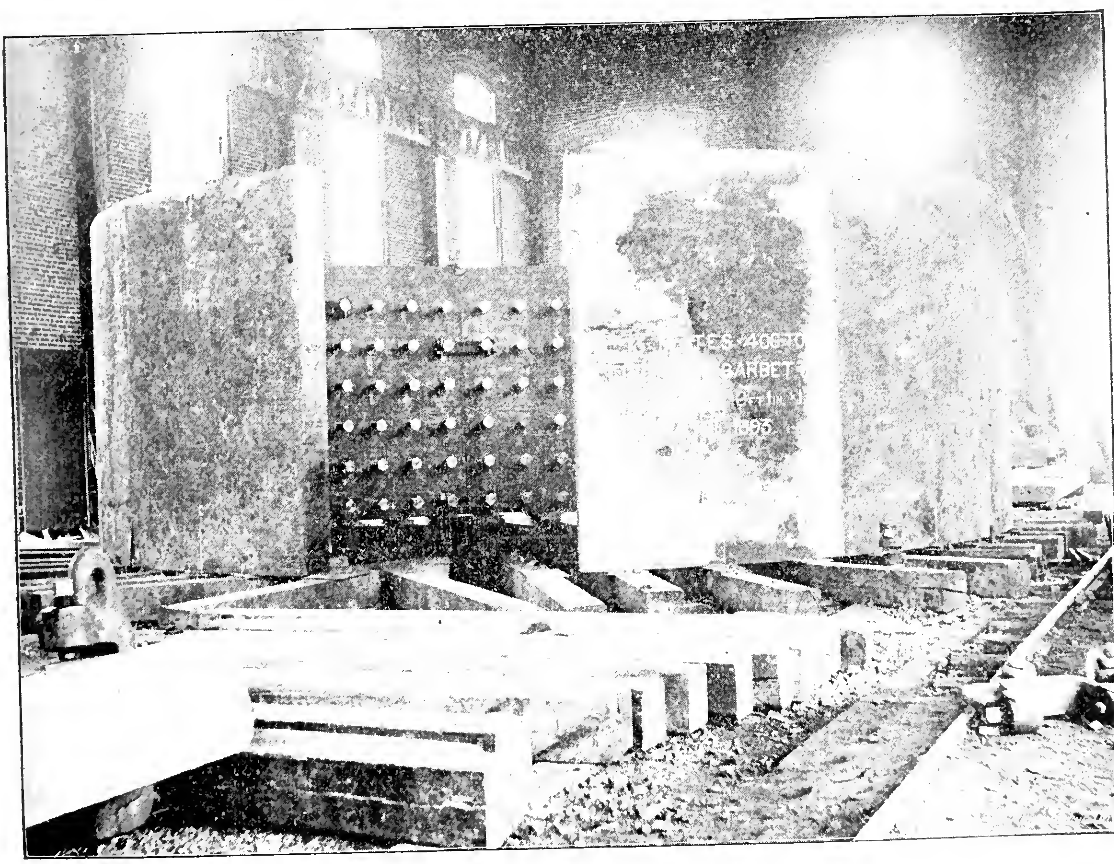


FIG. 190. Barbette for U. S. Battleship "Indiana," with one plate removed. Composed of 13 nickel steel plates, each 12 ft. 1 in. high, 8 ft. 4 in. wide, 17 in. thick, weighing 31 tons; total weight of Barbette, 406 tons.

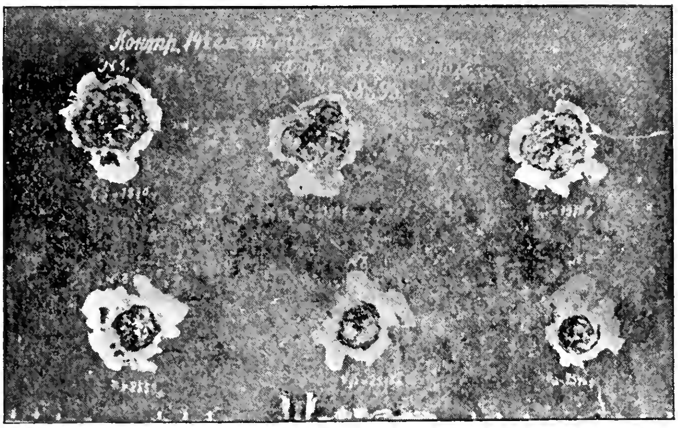


FIG. 191. Ballistic Test on 14½-in. nickel steel hard-faced Inside Armor for Russian Battleship "Sebastopol."

velocity, 1919 f. s.; striking energy, 10305 ft. tons. Penetration undetermined, projectile broke up.

Impact No. 3. 6-inch projectile, weighing 87.31 lbs.; striking velocity, 2558 f. s.; striking energy, 3965 ft. tons. Penetration undetermined, projectile broke up.

Impact No 4. 6-inch projectile, weighing 87.31 lbs.; striking velocity, 2546 f. s.; striking energy, 3928 ft. tons. Penetration undetermined, projectile broke up.

Impact No. 5. 9-inch projectile, weighing 403.16 lbs.; striking velocity, 1927 f. s.; striking energy, 10391 ft. tons. Penetration undetermined, projectile broke up.

Impact No. 6. 6-inch projectile, weighing 87.31 lbs.; striking velocity, 2573 f. s.; striking energy, 4012 ft. tons. Penetration undetermined, projectile broke up.

Now, to summarize in a few words. The object of using steel in preference to wrought iron is to obtain a metal that is from twice to four times as strong and, if properly made, is free from flaws and defects and absolutely homogeneous. To secure sound forgings of large size they should be fluid compressed and hydraulic forged. All forgings, of whatever size, large or small, should be annealed. To obtain the very highest results they should be hollow forged and oil-tempered.

I have now run over in a very general way the subject of steel forgings, which I said I would treat on. If I have made plain to you why the Bethlehem Iron Company have adopted the processes which they are now using for turning out forgings, I have accomplished what I started out to perform.

ELECTRIC TRACTION.

By Edward Barrington, Mem. W. S. E.

Read December 2, 1896.

The author of this paper does not pretend to have made any discoveries, but merely recapitulates the work of others in an unpretentious manner, and trusts some allowance will be made for apparent shortcomings in the style and text.

"It is well known that novices in every science are constantly making supposed discoveries, and these appear to them for a time so wonderful that they sometimes think they cannot fail to astonish the world, revolutionize science and immortalize themselves.

"It happens, too, that such discoveries are usually in inverse ratio to the discernment and intelligence of those who make them.

"A more extended acquaintance with facts and principles will often satisfy even themselves that their great discoveries are only the crude and exploded fancies of other men, and other days, long since abandoned as untenable and worthless."

The census returns for 1890 report one-fourth of the street railway companies, operating by electricity, and a more recent statement formulated by the "Street Railway Journal" places the proportion using electricity as six-sevenths, which is nearly correct at the present time, the electric mileage being 13,500 out of a total of 16,000 miles; exact figures are not obtainable. However, I append "Poor's" statement in the last edition of his manual:

Aggregate length.................................15,956 miles.

A gain of 6,294 miles in five years.

He further gives the following equipment:

Passenger cars	28,154
Motor cars	20,777
Dummies	206
Horses	28,621

Since 1891, the decline in the number of horses has been 162,000, or about 80 per cent.

The capitalization of the above companies is about $850,000,000 in stock, and $540,000,000 in bonds, an average of $88,000 per mile in stock and bonds as compared with an average of $60,000 per mile for steam railways.

The total amount invested in street railways is about one-tenth of the total amount put into steam roads.

In Europe last year, the number of electric street railways increased from seventy to 111; their length from 700 kilometers to 902 kilometers; their power from 18,150 to 25,095; and the number

of cars from 1,236 to 1,747. Germany, of course, leads with 406 kilometers.

In Pennsylvania, as a result of the introduction of electricity, the number of street railways has increased from sixty to over 500.

The rights and franchises in some cases were secured for speculative purposes, and 161 of the above have no lines in operation.

The electric railways resemble largely the steam railways in respect to characteristics of construction, equipment, operation and traffic; and it is only natural that they should eventually be placed under the same legal restrictions. At present, the trolley roads are as a rule, exempt from regulations as to speed, equipment and management.

There is a bill before the Ohio legislature placing electric railways under the control of the State railroad commissioner. He is to be empowered to regulate the operation of all such roads with regard to the safety and convenience of the public, prescribe the maximum of speed, fix the number of cars to be run and the intervals for running them, limit the number of hours in which employes may be required to work, and otherwise have supervisory authority. If electric cars are coming into the same field of service as the steam railways, carrying passengers, freight, mails and express, they ought to have as much supervision as the steam roads. Indeed, they require special oversight, because they occupy the public streets and highways.

The following table gives some conception of the remarkable advances of street railway mileage in some of our principal cities during the past sixteen years. It seems almost incredible. The present mileage is given in detail in order to exhibit the proportional amount of each system of motive power:

City.	1880.	1890.	1896.	Horse.	Electric.	Cable.	Miscellaneous.
New York City	130	180	418	237	31	50	100 Elevated
Chicago	80	190	890	59	677	82	72 Elevated
Philadelphia	258	277	489	—	489	—	—
Brooklyn	111	173	483	7	412	1	63 Elevated
St. Louis	63	115	381	5	331	35	10
Boston	95	238	454	34	420	—	—
Baltimore	46	100	279	—	243	36	—
San Francisco	57	89	294	33	131	104	26 Steam
Cincinnati	48	68	272	—	248	24	—
Cleveland	26	88	313	—	294	19	—
Buffalo	25	44	227	—	227	—	—
New Orleans	82	113	178	28	144	—	6 Steam
Pittsburg	39	66	435	13	373	49	—
Washington, D. C.	29	45	152	44	80	28	—
Detroit	27	59	223	—	223	—	—
Milwaukee	11	53	163	—	151	—	12 Steam
Minneapolis	9	58	123	—	123	—	—
Jersey City	15	47	175	—	175	—	—

The growth of street railway traffic in New York, in the last thirty years, is shown in the following table:

Date.	No. of Lines.	Elevated Traffic.	Total Traffic.
1865	11	———	79,618,818
1875	13	644,025	140,582,793
1878	15	9,236,670	169,105,739
1883	15	92,124,943	266,164,236
1893	16	219,621,017	453,652,964

The railway commission's report for 1895 says that the operating expenses, interest, taxes and rentals of all street railways in the State of New York, aggregated 91½ per cent of their gross receipts. At this rate, the dividend on one 5-cent fare amounts to 4¼ mills. In New York, a passenger can ride nineteen miles for 5 cents; in Brooklyn, twenty-one miles; and in Buffalo, thirteen and three-fourths miles for the same fare. Reduced to mile-rates, the transportation charge would be 2.6, 2.4, and 3.7 mills per mile, which is claimed to be the cheapest transportation rate in the world.

The St. Paul & Northern Pacific Steam Railway gives a ride of about twenty miles for 5 cents—the effect of trolley competition.

The Montreal Street Railway Company equipped their lines with electricity in 1892, and since that time the percentage of the operating to the total expenses has decreased from 82 per cent with horses to 59 per cent with electricity. The consumption of coal, which was of the Cape Breton bituminous variety, varied between 1.18 pounds and 0.94 pounds per ton-mile. The number of Watt-hours per ton mile was 282, and the number of Watts, 2,290, or 3.07 horse power per ton, the speed of the car being 8.12 minutes to the mile. The power was measured at the terminals of the generators. With less severe gradients, as in Toronto, where the streets were very level, about 30 per cent. less power was used than at Montreal.

The power house of the company, which was equipped with 24″ and 48″ x 48″ compound Corliss engines, required 2.89 pounds of coal per electrical horse power when the engines were run condensing as designed. For a similar period of twelve days, when they were operated non-condensing, owing to the lack of water, they required 3.93 pounds of coal to produce the same energy.

The number of Watt-hours generated per pound of coal were 257 and 190 for the respective conditions.

Lancashire boilers, with Green economizers, supplied the steam.

Horse cars are a thing of the past in the "Monumental" city. The rapid transit introduction was begun about five years ago, and one by one the surface lines have adopted either the trolley or cable. Washington is also rapidly superseding animal power, there being only two lines using horses entirely, and two lines using them in conjunction with the trolley. Some of these lines may soon be using compressed air motors.

The Great Berlin Horse Railway Company changed part of their lines this year, to give better facilities for carrying the people to

the exposition. The system used was the general electric, and the conduit similar to that laid on Lenox avenue, New York. Great satisfaction was given by the rapid transit furnished by this means.

The London Road Car Company, which runs 900 omnibuses, intends to supersede horses by motors as quickly as possible. A hundred of these motor vehicles will be placed on the streets this month, and three hundred more in January next.

The rapid multiplication of trolley railways in competition with steam roads, and the great increase in speed and frequency of trains which the growing competition has stimulated, has not been accompanied by corresponding increase of skill and care in operation. The work of running and conducting a trolley car is not usually looked upon as skilled labor, requiring experience, special education and certain inherent qualifications. Anybody who can turn a handle bar or collect fares is eligible to the position of motorman or conductor. The long training requisite, in regard to train rules and orders, signals, meeting and passing points, grades, curves, condition of rail, holding power of brakes, precautions against accidents, what to do when accidents occur, etc., to which steam railway men are subjected before they are given responsibility for life and property, has little if any place in the selection of the trolley operators. The movement of each independent car is placed absolutely in the discretion of the two men running it, without possibility of control by any system of train dispatching, although the suburban electric road is always single track and generally abounds in heavy grades and sharp curves, with the additional danger, ordinarily, of occupying a portion of the public highway.

The result of all this has already been seen in numerous accidents, including several of that most inexcusable form of accident, "head-end collisions," a fearful example of which occurred near St. Louis recently. The methods commonly employed on trolley roads furnish little check against the carelessness of untrained employes.

I might cite plenty of examples to show the immediate necessity of placing the operation of these roads on a higher plane of skill and experience than at present characterize them.

Indeed, the time has come when state and national authorities should place around this form of locomotion much the same restrictions which have long been considered necessary with regard to steam railway operation.

The Metropolitan Elevated Railway, which has a complicated train service over its main line and three branches, and starts trains at exceedingly short intervals, relies exclusively upon telephones for communication, train dispatching, etc.

The Denver Tramway Company has for years used a system of telephones at the terminal of the several routes, connected with a central station, where an operator or dispatcher directs the running of every car. This system comprises nearly 100 miles of road.

The Point Defiance, Tacoma & Edison Electric Railway has also been using the telephone to assist in operating the road.

It is found to be a saving of expense, gives a better service and is a check on the conductors.

The marvelous development of electrical theory and practice has naturally tended to make it the most important topic in the college courses of the United States, sometimes to a material abridgement of mechanics, acoustics, thermodynamics and optics.

The strength of public feeling against electric trolley railways has decreased considerably within the last few years, as people have come to understand better the small danger from overhead wires under ordinary conditions, and consequently we hear of fewer schemes for underground conduit constructions than we did formerly. There remain, however, enough objections, on account of unsightly poles and wires, accidents from broken wires, electrolysis, etc., to furnish an incentive to inventors to improve upon the trolley line by placing the wires underground. The cost will prevent a general use of this system except where there is heavy traffic.

Electric traction, in all our cities, has long been the dream of our engineers, and it may now be said it is realized, and before the end of the nineteenth century it probably will have completely displaced horses.

The decrease in percentage of working costs to gross receipts is surprising in spite of the additional capital, in most cases required, for the introduction of the electric plant, and there is no doubt but many unremunerative horse car lines could be made to pay by converting them into lines operated by electricity.

This is a rapid moving age; an era of electricity and high pressure steam; a day when men calmly and confidently discuss aerial navigation at rates of speed far in excess of those possible to even the swiftest of birds. It is therefore not at all surprising that the spirit of celerity should be found active in electric traction circles. In bygone years they have toiled steadily and successfully, but as a rule slowly.

Street railway interests are assuming wonderful proportions, with their 16,000 miles of track, controlled by over 1,000 corporations. There are new companies, consolidations, absorptions and syndicate purchases almost daily. It is pre-eminently an electric age, and we are only on the threshold. The horse and mule have almost disappeared, and the cable system will be confined to thickly populated districts in large cities; but there seems to be no limitations to the electric railways. Cable roads cost somewhat over twice the cost of electric roads. The capital stock of the former, exclusive of bonds, is 2.4 times the capital stock of the latter, assuming averages. Each dollar invested in a cable road will earn .00015 cents in one day, whereas each dollar invested in the electric road will earn .00020 cents in one day. About 90 per cent. of electric roads pay dividends of from 5 to 12 per cent. There is little room for improvement in cable road practice, whereas electric systems may continue to increase in efficiency—(earning capacity)—until all

rivals are distanced, and only one method of rapid transit is recognized—"the electric car."

Some cable roads are operated for 9.5 to 6.6 cents per car mile, exclusive of interest on bonds only; and others for 55 to 42 per cent. of gross receipts; and others for 2.75 to 1.5 cents per passenger; they burn only one pound of coal to three for the electrics.

Within a comparatively few years the horse railways of St. Louis, Chicago and some other large cities, have been converted into cable roads, and now about 180 miles of cable roads in Pittsburg and Washington, D. C., are to be transformed into trolley and underground electric roads.

In Philadelphia the cable has given place to the trolley, while about all the cable lines of St. Louis have for some time been operated by electric current carried by an overhead wire.

The authorities and people in New York City have stubbornly opposed the trolley from the outset, and possibly an understanding of this sentiment has prevented an attempt to transform the existing street railways in that city into trolley roads.

There are to-day about 16,000 miles of street railway in the United States, of which about 13,500 are operated by overhead wires. These persistent facts serve to indicate the rapidity of changes in street railway propulsion and also the lack of stability in the older systems, and raise a question as to the permanence of the trolley system. Vast sums have been wasted in these changes and are now invested in the trolley and are dependent for security largely on the permanence of this latest and most profitable system of propulsion.

The first cost of the cable roads was excessive, while the operating expenses were reduced by them to an almost absolute minimum. The serious objection to the cable roads is that the speed must be constant or nearly so, and that lost time cannot be made up by increasing speed in the least thickly settled portions of cities or in the suburban districts, as it can be with the trolley. This is no doubt the chief reason why the New York City street railway managers are seeking for some system other than the cable which will be acceptable to the people.

The public must travel fast, and is evidently prepared, in most cases, to pay for increased speed; so that to-day the average speed of street railway cars throughout the country is probably 50 per cent. greater than it was ten years ago, and the people are learning to accept their part of the sacrifice necessary to maintain speed. They are gradually learning to move quicker and to lose less time in getting on and off cars, and even to look on the increased injuries and fatalities attendant on a rate of speed, until now unprecedented in city streets, if not with complacency, at least as a part of the inevitable price of the benefits secured.

Many bitter lessons have been learned by stockholders and even by managers of city lines. High speed cannot be safely maintained with imperfect road-bed and rails. One city is now relaying fifty miles of double track, laid with a "U" rail which, in substantially

the same form, had been discarded by steam roads fifty years ago, the loss to the stockholders from this experiment exceeding one million dollars.

Ultimately, no doubt, we shall come to the road-bed in use in Minneapolis, Toronto and Montreal, where a girder rail, with broad tread, is laid directly on a concrete foundation, which also carries the pavement, for the maintenance of which the authorities have made the railways responsible. Thus economy in maintenance of way and pavement is forced on the railway and secured by the public at large, and the gain is alike mutual and progressive toward high ideals of municipal improvement.

The American people are perhaps too apt to conclude that in matters of this nature the end justifies the means, and accordingly while the street railway road-bed and the cars are being rapidly perfected and the systems are operated generally at a considerable economy over the old horse roads, little is asked as to whether there is any other system as rapid as the trolley and more economical, either in first cost or in operation. Probably some such system, electrical or otherwise, is possible, and will be developed in the fullness of time. Meantime it is a source of gratification that our street surfaces are being improved and our transit made more rapid by this same trolley, which, on account of the excellence required in its road-bed and the relatively small expenditure for its wires, will lend itself the more easily to the new and better system of the next transformation, which many believe is near at hand.

A prominent feature in the reign of the overhead trolley has been the unanimity of expression in electrical and engineering journals, whenever there has been opportunity to compare the overhead trolley system with anything that promised to be an improvement, upon that crude application of electricity to motor purposes.

No matter how meritorious any of the new inventions seemed to be, their excellencies were invariably decried, but the day of such slavishness is departing and there are now several publications which frequently admit that there are better systems than the overhead trolley. Of these, the "Western Electrician" does not seem to be one, for it states that "the electrical men are still undisturbed by the recent attention paid to 'compressed air traction,' because they believe that in the essential feature of economy the pneumatic system will never be in competition with the overhead trolley." The "Engineering Record," though an authority of high rank, seems to be convinced that "not only the overhead trolley, but the underground trolley, and the cable system also, will in the near future be superseded by a more modern form of motor." It quotes facts that show conclusively the lack of stability in the older systems of street car transit and from conclusions thus deduced it questions the permanence of the trolley system. Says the Record: "We have heretofore expressed the opinion that the electric trolley system is not the ideal system that it has been held by many to be for handling the local passenger traffic of a large city. The objections urged

of the unsightliness of overhead construction and the speed at which the cars are run, have as much weight now as when first formulated. A system less noisy, less unsightly, less dangerous, and more economical in operation, while still as rapid as the one now in general use, is greatly to be desired, and may be considered among the possibilities of the not distant future." This is very much of a concession. It indicates that those great corporations which have been the mainstay of the overhead trolley system realize that they have about reached the limit of their personally profitable endeavor to force the overhead trolley upon every community. In Washington they are free from the murderous nuisance which has afflicted so many other cities. By persistently opposing every effort of the "trolley magnates," they have, as a result, rapid transit facilities far in advance of those possessed by any other city in the country. And it is among the possibilities that they will in the near future stride still further to the front in this very important matter.

The overhead trolley system should be exclusively confined to suburban districts, and the underground system inside the cities proper, or "self-contained accumulator cars."

The conduit system is successfully in operation in New York, Chicago and Washington, the conduits being about the same dimensions as those of the Chicago cable roads, but the expense is prohibitive for suburban lines and for switching yards.

The underground electric system, as in operation in New York and Washington, D. C., is worked at an estimated saving of four cents per car mile under that of the cable system, and costs less than $60,000 per mile.

The Love system of underground conduit for street railways is to be installed on a quite extensive scale in Chicago, the General Electric Railway Company having secured a franchise for about eighteen miles of line on the south side of the river, upon which this system (similar to that used at Washington, D. C.), is to be used. Some additional twenty miles will be constructed on the completion of the above.

This line will run between Jackson street and Fifty-seventh street.

It is hoped the early introduction of some underground system will insure the eradication of the overhead construction, as it would do away with the public objection of disfiguring the streets, obstructing firemen in their duties, and in the case of high tension currents, a menace to life itself; and then the liability of wires falling, causing a suspension of traffic, and, in case of a storm, causing a delay and serious pecuniary loss to the company.

The present underground system is a success undoubtedly, but the excessive cost bars it from general introduction. The Siemens-Halske system, as in use at Buda-Pesth, Dresden, and elsewhere, seems most nearly to approach the ideal underground system.

The Manhattan Elevated Railway, New York, has been making tests of the electric system, which have been highly satisfactory, and they may soon adopt it, more especially as the company cannot

continue indefinitely to pay 6 per cent. dividends on 4 per cent. earnings, as it has been doing recently.

This will bring about a reform in cleanliness, speed and lighting. The third rail system will probably be used, in connection with storage batteries as an auxiliary, in case of accident.

The motors will be similar to those used on the Chicago elevated railways.

The storage batteries are capable (without the third rail conductor) of propelling a locomotive at a speed of fifteen to twenty miles an hour, a distance of thirty-six miles, so that accidents in the power station would not stop operations.

Last winter the management of the Chicago elevated railways were much elated over the manner in which their equipment withstood the severe test of the great November storm which to a considerable extent paralyzed surface lines. Cable and trolley lines were then operated only at long intervals and with great difficulty.

After some months occupied in reconstructing the machinery of the Lake Street Elevated Railway Company, it has again begun the operation of its lines by electric motors, and the steam locomotives have been discarded. The defect in the trucks which caused a suspension in the use of motors immediately after their introduction has been remedied and the electric service now appears to be moving satisfactorily, barring some confusion in the dispatching, from the attempt to run trains two and one-half minutes apart, which has caused several bad blockades during the busy hours.

Two of the elevated roads are now operated by electricity, the Alley is to change from steam in the near future, and the two other elevated roads that are now under construction will be run by electric motors from the start. The steam locomotive will soon disappear forever from street railway service in Chicago, and the time will come when it will not be permitted to enter the heart of the city on any railway.

The Lartigue rail system is about to be tried in Belgium, where arrangements have been made to construct three miles of line at the Brussels exposition. The track will be oval in shape, and a speed of ninety-five miles per hour has been guaranteed on the end curves, which have a radius of 500 yards, and 100 to 150 miles an hour on the straight track.

The Listowel & Ballybunion Railway in Ireland, and the "Feurs & Panissieres Railway" in France are built on this system and have been in operation for some time without the slightest hitch.

It is practically impossible for a train to be derailed.

An underground electric railway is proposed for Brussels, at an estimated cost of $3,000,000 for the complete circle of four miles. The tunnels for the two tracks will be separate, and will run almost entirely under the public streets, fifty feet below the surface. Elevators, operated by hydraulic power, will carry forty passengers each to and from the upper air.

The Buda Pesth Electric Railway tunnel is rectangular, 19.7 feet wide and 9 feet high, with a row of columns in the middle.

The Boston Electric Subway, likewise, is rectangular, 24 feet wide and 15 feet high, without a central row of columns, except on the four-track section, where the columns support the roof of a tunnel section 48 feet wide and 15 feet high.

The seven underground electric systems of London are all designed with a separate tunnel, of circular section, for each track.

One of these is in operation, one nearly completed, another just commenced and the remaining four will be under way shortly.

These roads are all built by the aid of the "Greathead shield"—an air lock system—which enables work to be executed expeditiously at any depth in perfect security, and to be continued unhindered, quite irrespective of whatever springs may be encountered while boring. The average depth below the surface is sixty feet. Trains will run at two and one-half minute intervals. The cost of construction and equipment is calculated at $2,500,000 per mile. Hydraulic lifts will convey passengers to and from the trains, and subways will be constructed for foot passengers to cross from one side to the other of the tracks.

The tunnels are 11 feet 6 inches in diameter, and these lines are expected to be in operation by December, 1897.

To give an idea of the magnitude of these combined railway enterprises the number of new stations involved will reach a total of forty-five.

At the last annual meeting of the "Tramways Institute of Great Britain and Ireland" one member read a paper on "The Mechanics of Horse-Haulage," maintaining that the traces are generally attached at the wrong place. He also incidentally maintained that the horse is the best and cheapest motor in existence. This created considerable discussion. Another paper was read on "Mechanical Haulage on Tramways," which advocated the cable system and maintained that the history of electric traction for tramways has been one continuous record of financial failure. As the other statements in the paper were in a line with this, it is useless to follow it further. Is it surprising that electric traction is not making more rapid progress in that benighted country?

For some months the New York, New Haven & Hartford Railway Company have been operating their Nantasket Beach branch by electricity, the overhead conductor being used on a portion and the third rail system on the balance. The success it has met with simply confirms the predictions of the engineers, and the traffic is phenomenal. Railroad managers throughout the country are watching this experiment, under the ordinary conditions of constant travel, with great interest.

About a year ago many people thought the climax of electrical achievement had been reached when the Baldwin & Westinghouse companies formed an alliance, and supposed this was surely a forerunner of rapid transit revolution, and naturally so.

The revolution, or evolution, will assuredly come, but more in the form of an extension of improved street car service, rather than a wholesale substitution of electric motors for steam engines.

It is admitted that the electric locomotive, with its most recent improvements, and its reinforcements in the form of "Tesla" patents, is not yet equal to the steam locomotive for general railway work. The motor's superiority in some kinds of train service is admitted and beyond dispute, such as suburban traffic. Trunk line roads can be operated cheaper by steam, but where the distance is short, the service frequent, and the trains light, electricity is most economical and more free from dirt and noise. The motor can accomplish much in this broad field before considering greater problems; and it should be classed as an ally rather than an enemy of the steam locomotive. For switching and general yard work overhead trolley lines appear to be impracticable, chiefly on account of the pole obstruction. The Westinghouse Company hope to overcome this by placing the wires underground and using their "button" system of contact. An example of this system has been operated on the North Capitol street line in Washington, D. C., and a speed of twenty-six miles per hour made. It runs perfectly smooth, and without rumble or harsh grating sound, so disagreeable in the trolleys. The electro-magnetic switch, or "button" system, is quite different from the "Tesla" system, inasmuch as they can be used together or separately. The "button" system is simply a means for collecting current from the conductors and conveying it to the cars and motors.

The "Tesla" motor is not a great departure from old methods, though it contains several new features and new applications of old principles. The "multiphase" or "alternating" current is used and the commutator done away with. The machine is controlled by one single switch. I cannot enter upon an extended description of the "button" system, suffice it, that the conductor is at the side of the track or between the rails, and is buried in the ground and covered with lead like an ordinary electric cable. It costs about the same as the overhead trolley, and should supersede it in the cities instead of the underground system now in use. For double track lines the conductor is carried between the tracks, but for single track suburban lines or others it is placed in wooden troughs between the rails, directly under the cars.

A somewhat similar system is in operation in Paris, the working of which is being closely watched, as it is the first extensive road—(10 miles long)—to be equipped with surface contacts on the street and automatic switch boxes.

This system is also being installed on a large scale at Pittsburg. This action is viewed as a fresh blow to the deadly trolley, and as tending to relieve the people of crowded cities from danger to life and property from the trolley, and also to remove the unsightly poles and wires which disfigure so many of our otherwise beautiful cities.

The third rail, or conduit, systems are practically impossible for suburban lines, such as the "Illinois Central" for instance, but the trolley system is practicable in every way, except that of pole obstruction, signals and approaching trains being shut out of view, hence the advantage of the "button" system as already suggested.

The speed of electric locomotives is limited only by the wishes of the operators. Ordinarily the speed is kept down to the required maximum by arranging the gearing with a driving pinion much smaller than the gear on the axle. To increase the speed all that is needed is to enlarge the driving pinion.

What is wanted is not great bursts of speed, but a higher average than is now maintained. The public will not support a more expensive service. Where electric service is adopted, the operating expenses are generally reduced, and the fares can be lowered, and a greater volume of business results. The Mount Holly branch of the Pennsylvania Railway—a trolley line—is a proof of this. It has become so popular that the fares have been reduced. The same will be true of any line built where there is naturally a good traffic, and this will soon be realized by railway managers.

When the rolling stock now in use is worn out and has to be discarded it will be replaced by electrical traction stock.

For short lines the advantage of the "Tesla" system is confined mainly to the simplicity of the motors, but for such lines as between New York and Philadelphia, Chicago and Milwaukee, or Baltimore and Washington, the number of stations required with the direct current is so great that the first cost and the fixed charges would be very high. With the "Tesla" system two stations between New York and Philadelphia would be ample, while at least nine would be required with the direct system.

The cost of operation and the fixed charges incident to the first cost of equipping long lines with electricity have been and are now the two factors which discourage the use of electric motive power, and it is only where traffic is heavy that the fixed charges and the cost of operating the central stations can be permitted. With the "Tesla" system the operating expenses are reduced to a minimum, owing to the few central stations, the decreased repairs and the efficiency in transmitting the current; and the fixed charges are less, as the conductors are cheaper, and the central station first cost is not more than one-third as much as for the direct current.

The great advantage of the electric system is the possibility of giving a more frequent service with the same total cost for operation. That is, a train of two or three cars could be sent out every fifteen minutes from either terminus, and make a high rate of speed, without increasing the cost of operation above what it would be when the trains are dispatched about one hour and a half or two hours apart.

If the traffic will bear the cost of construction the project is bound to be a financial success, more especially where existing roads have already terminal facilities secured.

Electrically and mechanically the problem is simple.

Several Chicago roads have long been considering the advisability of substituting electric motors for steam locomotives, and should they decide to do so finally, they need not go outside of Chicago to obtain their necessary equipment, as the Siemens & Halske Company is possibly fully prepared to furnish any amount of equipment of this character.

Two weeks ago the Buffalo Street Railway began using 1,000 horse-power of electrical energy transmitted from the falls of Niagara, a distance of about twenty-six miles. The great dynamos in the power house at Niagara Falls are marvelous makers of electrical energy. Each of the four has a capacity of 5,000 horse-power, even when the turbines below develop an efficiency of only 75 per cent. The plan of generation is known as the "Tesla polyphase alternating current" system. Each generator delivers an alternating current to each of two circuits. The two currents are 180 degrees apart, that is, each current attains its maximum value when the value of the other is zero. The direction of the current is reversed 3,000 times per minute. The current thus produced is conveyed through heavy lead-covered cables to the small transformer house on the opposite side of the canal from the dynamo house. Here the wires enter what are called "step-up" transformers, whence the current is converted into one of high potential, e. g. of 20,000 voltage, for transmission. Then the current leaves the transformer house on a heavy wire and is launched on its long journey. At the city line of Buffalo the "step-down" point is reached. Here another power house is found, where the potential is reduced and the current again put on the wires and carried into Buffalo to the railway company. Thus is harnessed the great Niagara, without marring a single feature of its wild and grand beauty, the consummation of the blending of the useful and the beautiful, without destroying a fairyland of beauty and enchantment.

The use of high voltage greatly economizes first cost on installing an electric railway on account of the saving in copper, but the danger to life and property is increased with the voltage.

On existing trolley lines a maximum voltage of 550 volts is used, but as greater amounts of power will be required for heavy traffic, a higher voltage will be economical and it is proposed to use 1,000, or 2,000, or even a greater number of volts.

Should this be done, it will become necessary to have perfect insulation. It will be very expensive to obtain this insulation underground, and it would be much cheaper to put the wires conveying the electricity on thoroughly insulated poles. It is a question whether the Westinghouse Company can operate successfully with their system, and at least a year's practical use under all varying conditions of weather and wear and tear will be required to prove its success.

The worst conditions for electricity as a motive power is a rather infrequent service with a heavy train. Mr. L. H. Parker of the

General Electric Company believes it is possible to place a third rail conductor either between the rails of the track, or at the side of the track, that will be an efficient and practical substitute for the overhead trolley. A low voltage would have to be used and ordinary precautions taken.

The electric locomotive exhibited by the General Electric Company at the Chicago Exposition, 1893, having a rated draw-car-pull of 7,000 pounds, has been purchased by the Manufacturers' Street Railway Company of New Haven, Conn. It is equipped with air brake and its total weight is thirty tons. It will be utilized to haul freight cars from the junction of the New York & New Haven Railway at Cedar Hill, which is about one mile from the New Haven passenger depot, to the works of the Bigelow Company, manufacturers of boilers, the National Pipe Bending Company, the Quinnipiac Brewing Company, the New Haven Rolling Mills, and other manufacturing establishments located along the water front at some distance from the freight yards of the consolidated road. The freight cars will be hauled directly into the yards of the manufacturers and the loads will be collected by the electric locomotive and hauled to the main line of the railway, where they will be taken up by the steam locomotive for transportation to their destination. The length of the line along which this locomotive will run is nearly two miles, the maximum grade against the load being about 2½ per cent.

The guaranteed speed of this locomotive on this grade will be seven miles an hour with a heavy load behind it. All the locomotives which the General Electric Company has built will be—when this one is delivered at New Haven—in service.

The forty-ton locomotive is used as a switch engine at the Taftville Cotton Mills, at Taftville, while the three ninety-six-ton locomotives are engaged in hauling the freight trains through the belt line tunnel of the Baltimore & Ohio Railway, at Baltimore, Md.

On the Turtle Creek Railway, a branch of the Pennsylvania, near Pittsburg, there are two Baldwin-Westinghouse electric locomotives in use, which are respectively 400 and 800 horse-power, being designed for totally dissimilar purposes. Strength and solidity have been considered at every step, and the results are wonderfully powerful and heavy motor cars, weighing 120,000 and 160,000 pounds respectively.

They can be worked either with the trolley or upon the "wheelless" or "button" system.

The electric locomotives used in the Baltimore & Ohio Railway tunnel at Baltimore were thoroughly tested, hauling passenger trains at high speeds satisfactorily, and freight trains of fifty-two cars, weighing 1,900 tons, up a grade of forty feet to the mile at a speed of twelve miles per hour, starting the train on the grade easily. The current record on the ammeter was 2,200 amperes during the acceleration period, and after the train was up to speed it settled down to 1,800 amperes. The voltage on the line was 625. The draw bar pull being 63,000 pounds.

On the Brooklyn bridge the steam locomotives have been superseded by electric motors. The only apparent change in the cars is that the trucks are more massive, and there are two collectors on the roof. All the electrical apparatus for controlling the motors is hidden from sight beneath the car, and all that can be noticed, unless specially looked for, are two additional spindles on the platform. The electric motor car will be used for switching purposes principally, for which a certain number of cars will be furnished with four motors, one on each axle. One of these motor cars will be attached to each train, remaining constantly with it, switching from the incoming to the outgoing tracks, and pulling it over the tilting sheaves, when the grips will take up the cable and the current from the motors will be shut off. In mounting the steep grade to the center of the bridge, if the grips should slip, the motors can again be put in service to assist the train over the summit.

There are quite a variety of electric locomotives now on the market, viz.: Express, freight, switching, suburban and elevated, mine, rack, etc. The cost of operation, including labor and repairs, is undoubtedly low. On heavy grades, in a rolling country, it can haul a greater paying load than a steam locomotive of the same power, as all weight unnecessary to secure traction is removed. A less expert class of help is used for operation and repairs, and one motorman takes the place of engineer and fireman on a steam locomotive.

For hauling in mines the electric locomotive is superseding steam and mule power. It does not vitiate the air; there is no danger of igniting gas; only a small amount of apparatus is necessary; the weight of locomotive is small compared with other systems, and the capacity for hauling on grades is very large.

It is very serviceable for switching in yards, especially where electricity is used for other purposes, as it is easy to repair, simple to operate and inexpensive to maintain.

The electric locomotive is fitted with air brakes and a whistle fed by compressed air, which is supplied by an electric air pump.

The third rail system, as used in this city, is satisfactory, electrically and mechanically, but it cannot be used where passengers have to cross the track, and where switchmen have to constantly prowl about in the darkness. It is not seriously thought of, except for elevated roads.

When not in use there is little deterioration in electric locomotives. Where the service is intermittent, power is saved when the locomotive is idle.

It is scarcely necessary to add that the Baldwin Locomotive Works and the Grant Locomotive Works furnish all types. The workmanship and material are of the best, and the details of construction are most carefully supervised.

The mine electric locomotives are more compact than heretofore, and the width is less, although the parallel rods are used. The details are simple in form and accessible for repairs.

Most electric locomotives have to be increased in weight to give the desired tractive power.

The objections to the gearless motor are less in theory than in practice. For street work they have proved so inefficient that they have been abandoned.

The efficiency of the 100 horse-power motor when developing 100 horse-power at 500 volts, which is the condition of the normal full-speed running, is 88 per cent. between the electric circuit and the armature-shaft pinion.

It is 89 per cent. at sixty horse-power and 84.5 per cent. at 170 horse-power. At 250 volts, which is the condition when two motors are connected in series for about half-speed, the efficiencies for the corresponding torques vary between 86 per cent. and 77 per cent. At 125 volts, which is the condition on a 500-volt circuit when four motors are in series and the speed is low, the efficiency for corresponding torques varies from 83 to 62 per cent. The friction of the gears will reduce these figures about 3 or 4 per cent. for the efficiency between the armature-shaft pinion and the driving axle. A resistance or rheostat is placed in circuit at the moment of starting and at intervals while the motor is being brought up to speed, and the efficiency is reduced while the resistance is in circuit. If the time of starting be short, the reduction in average efficiency due to the loss in resistance is small. The average efficiency between the electric circuit and the driving axle will not, except in special cases, be less than from 70 to 85 per cent., depending upon the proportion of time at which the motor is run at slow speed.

The draw bar pull depends upon its weight upon drivers, as the torque or pull of the electric motor is sufficient to slip the drivers. The total weight of the locomotive may be upon the driving wheels; carrying wheels, or wheels without motors, being unnecessary except in special cases.

A novel combination of steam and electrical service is about to be inaugurated by the Columbus, Hocking Valley & Toledo Railway. Having completed a seventeen-mile extension to Jackson, Ohio, the company has established three trains each way to and from Columbus, and announces that, in addition to this service, on the portion of the extension from Wellston to Jackson, about nine miles, electric trains will be run on an hourly schedule to better accommodate its patrons. There is many a piece of railway in this country on which traffic does not justify running more than two or three steam trains a day, and yet would warrant running a trolley car at frequent intervals. The track being provided, this additional accommodation could be furnished at small cost.

The St. Louis tunnel is an excellent place in which to substitute electricity for steam in the movement of trains. Notwithstanding the speed with which travelers are carried through this subterranean connection between the union station and the great Eads bridge, considerable discomfort is experienced from the fumes of carbonic acid gas that enter in spite of the closed transoms, while the smoke

and steam that shut in the train increase the danger of accidents. The situation has many difficulties not easy to overcome. It is not thought practicable to work the traffic with electric engines over the complicated network of tracks and switches between the union station and the tunnel, and a double service of steam engines would therefore be required, as would also be the case across the bridge. For the roads which now bring trains into the station with their own engines the proposition to cut off their locomotives at the river would involve serious considerations. The fact that the St. Louis tunnel is used by a number of roads makes the conditions very different from those in the tunnel of the Baltimore & Ohio road under Baltimore, which is so often cited as evidence of the practicability of working electric locomotives in all tunnels. Still the advantages of using a steamless, gasless motor in this thoroughfare are so evident that the reform will doubtless be eventually effected.

In Paris mechanical power is making great progress. Ordinary and fireless locomotives, compressed air and electric motors are now used on several lines, and the "Belleville" tramway is operated by a cable. The rails are of the American flange and Broca or Marsillon types.

It is reported that electric locomotives will soon handle all traffic through the "Hoosac Tunnel," on the Fitchburg Railway. The electric lighting of the tunnel some years since has not accomplished the result hoped for. The smoke and gas from the engines still remain and the lights are more or less hidden from view.

The combination of electric lighting and the use of electric locomotives, together with the ventilation already in use, will, it is hoped, take away entirely all the disagreeable features of the tunnel that have existed in the past.

The Baldwin-Westinghouse combine have just turned out an electric locomotive, different from anything of the kind ever attempted before, which has made 120 miles an hour privately, and which is credited with a possible speed of 200 miles per hour. There is little mechanism visible, as the motors are hidden in jackets of steel. It is considered the most complete locomotive ever turned out, and does not in the least resemble outwardly the conventional appearance. The frame is made of ten-inch rolled steel channels, surrounded by a half-inch rolled steel plate, covering the entire floor. This plate gives great strength to resist blows in collisions. The frame is carried on two trucks, which have all the easy riding features of car trucks. This is positively the first electric express engine. The trucks are of the swivelling type, and can pass any curve that a regular freight engine can. The geared connection between the electric motors and the axles permit the use of any sort of gear ratio that is suitable to the desired speed, and make this locomotive adapted in all mechanical details for slow or high speed. It is adapted for both the direct current and the Tesla system. Every feature that will reduce loss of motion, even by a fraction of a second, has been carefully considered.

The driving wheels are so arranged that they may be coupled with parallel rods (when the train to be hauled is heavy), to prevent slipping. The weight of this locomotive is 150,000 pounds, and thirty-seven feet in length, over pilots. A controller at either end takes up a small space inside. The motors are directly beneath the car bed, between the two trucks. They are entirely encased by thin steel shells, and are free from injury under all normal conditions of service. The armatures are laminated, and are made up of thin slotted disks of steel. In the slots are placed the armature wires. The commutators are of the best forged copper, with mica insulation of the highest grade. The third rail system is used. It is expected to maintain an average speed of 150 miles per hour easily. Of course, we all understand, that with existing systems of railroad, such a speed could not be attempted; but when some enterprising railroad abolishes all grade crossings, elevates its tracks, changes its signal system, and insures a clear way of at least one and a half miles, here is a locomotive ready for record-breaking. Our fellow member, Mr. David L. Barnes, is the designer of this extraordinary locomotive, and would doubtless be pleased to give further particulars regarding its details.

The new subway in Boston is rapidly approaching completion. It is unique in many respects. The cars on the overhead trolley system will leave the surface, and by a rapidly descending grade enter the double track subway, with underground stations at frequent intervals. The subway will relieve the streets in the congested sections of the city very considerably. A unique feature of the system will be the terminal arrangements at points where the different routes end. Instead of returning upon the same track or by means of a cross-over passing to the other track, the car will continue forward past an "island" station, and by a descending grade and a loop with an ascending grade return to the former level and the opposite track. High speed can be maintained in sections of the city where it would be otherwise impossible.

ELECTRIC TRACTION BY STORAGE BATTERIES.

This system of traction is operated upon an extensive scale at Nice, Dresden, Hague, Hanover, Manheim, Birmingham, England, and elsewhere very successfully.

On the St. Denis line, Paris, the electric cars are also run by accumulators. The car weighs 16,500 pounds; the accumulator battery, 6,600 pounds, and the passengers, 7,700 pounds, a total of 30,800 pounds. The battery contains 108 cells of eleven plates each, arranged in twelve wooden boxes, six on each side of the car. These boxes can be withdrawn and replaced by charged boxes in six minutes. When fully charged the car can run thirty-seven miles on the Broca type of rail, and twice that distance on a "T" rail. The cost per car mile of operating the car is set down at 14.48 cents, as compared with 9.24 cents per car mile for overhead electric traction in Paris. This cost is divided as follows:

Handling accumulators	1.84 cts.
Maintenance of same	3.08 cts.
Maintenance of motors and trucks	1.56 cts.
Motive power	5.54 cts.
Wages and superintendence	2.46 cts.

With a new accumulator system tried lately the cost is stated to be only 10.46 cents per car mile.

The Englewood & Chicago Electric Street Railway system is equipped with the accumulator system. The batteries are supported on a tray, placed between the axles, instead of under the seats, as usual. The electrical equipment consists of sixty cells of battery, grouped in two series of thirty cells each, which operate two twenty-five horse-power motors wound for a speed of twenty-four miles an hour. The cells are of the nine-plate traction type.

For the past three years a storage battery has been in operation as an auxiliary to the power plant of the "Government Electric Railway," at Sydney, New South Wales. The battery is located at one end of the line, two and one-half miles from the power station, which is at the other end. The generators for the electric road are driven from a Corliss engine, which also drives two cable lines. The battery averages up the generator load, so that only one-half the usual generator capacity is necessary. A durable battery, costing $1,000, which will take the place of an engine and generator capacity sufficient to deliver 70 to 100 amperes in a small plant is certainly a good investment.

The Union Traction Company of Philadelphia has installed a storage battery plant at the end of a feeder, eleven miles long, for regulating purposes. The battery supplies current to a recent addition several miles in length. It was found necessary either to build a new power house or install a battery sub-station, as the required addition to the existing feeder system would necessitate such an enormous outlay for copper as to render it commercially impossible. It was found that the cost of copper alone to carry out this intention and double the service on the section would be four or five times the total cost of a battery installation to fully meet all requirements, and that a new power house was out of the question on account of the heavy operating expenses.

Before the extension was made the pressure at the end of the feeder was barely enough to operate cars on schedule time, and the pressure varied as much as 50 per cent. The load on the section varies from 100 to 700 amperes; the feeder carries a constant load of 400 amperes, the battery discharging or charging to the extent necessary to maintain this condition. The result in actual practice is found to be that the feeder load remains constant at this average current and is absolutely independent of the fluctuating demand on the line. The battery house contains 240 cells of the "G" Electric Storage Battery Company's chloride accumulator, thirteen-plate type. The maximum discharge rate of the battery is 400 horse-power for one hour. The plates are in lead-lined boxes.

In central stations storage batteries are of great value in many ways; in fact, it may be said that there is no continuous current central station plant in existence which cannot be operated more successfully and economically with the assistance of a suitable storage battery equipment than without.

The chief points of advantage are:

First—Reduction in coal consumption and general operating expenses, due to the generating machinery being run at point of greatest economy while in service and being shut down entirely during hours of light load, the battery supplying the whole of the current.

Second—The possibility of obtaining good regulation in pressure during fluctuations in load, especially when the day load consists largely of elevators and similar disturbing elements.

Third—To meet sudden demands which arise unexpectedly, as in the case of darkness caused by storm or thunder showers; also in case of emergency due to accident or stoppage of generating plant.

Fourth—Smaller generating plant required where the battery takes the peak of the load, which usually lasts for a few hours only, and yet where no battery is used, necessitates sufficient generators, etc., being installed to provide for the maximum output, which, in many cases, is about double the normal output. For this purpose alone it has been demonstrated that a battery is a profitable investment, the cost being equal, or, in fact, less than the generating plant required to supply the maximum output, and when the other advantages are considered, there is no doubt whatever that the storage battery is an essential feature, both technically and commercially, in a central station plant.

If storage batteries are used the two types of variable load belonging to lighting and power stations demand different types of battery. For lighting stations a considerable capacity is required, while the momentary variations of power stations do not require any great capacity, but demand as great a maximum output as battery manufacturers can obtain.

In water power plants the conditions of economy are different. The location of the plant is, of course, definitely fixed, and the advisability of obtaining a uniform load, by means of batteries, depends upon the local conditions. If the water power is limited, and is less than the demand, then it might be well to use batteries, in order to increase the amount of salable power. Again, if the development is expensive, it might be cheaper to develop a smaller amount of power, pay for a smaller amount of machinery and increase the output by the addition of batteries. These questions can only be decided by a knowledge of the local conditions.

Engineers have tried many methods to get over the trouble caused by "variations of load." There are some curves taken by the Cleveland Street Railway Company in which the amperes jump from 4,500 to 3,400. The chief cause of these great and sudden variations

is when fifty or sixty cars happen to start all together; which is quite possible. Accumulator batteries, as used in the Isle of Man, Zurich, Sydney and other places, seem to fill this purpose well, and repay their first cost in four years.

The time has gone by when it was safe for a central electrical station engineer to decide off-hand that his plant did not need a storage battery, or to say that it was not a legitimate piece of apparatus, that it was unreliable and unrivaled in its money consuming ability. A commercial battery is now obtainable and it has as much right to consideration for central station work as older or better known apparatus.

The situation is different in this country from Europe. In Germany and Austria 80 per cent. of the direct current stations are equipped with storage batteries. In France the company manufacturing the "chloride accumulator" turns out several tons of plates a day. In England the application, while confined principally to small isolated plants, is very extensive in this class. It is not improbable that to the advantages in the use of the accumulator is due the predominance of direct current stations over those using alternating current throughout Europe, and conversely in this country.

In central station practice storage batteries are made use of to take the "peak" of the maximum load, to act as an equalizer or reservoir, to take the entire minimum load, and to equip annex stations.

In the load of city trolley stations there is a morning as well as an evening "peak," due to the great volume of travel at those times, while in lighting stations the "peak" occurs only in the evening.

The tendency of passenger transportation on the steam lines has been in the direction of the greatest electrical economy, while the tendency of the freight transportation has been in the direction of the least electrical economy.

It will not pay any through line with considerable traffic, having two tracks, to equip its main tracks electrically.

With four-track roads it will pay to equip all of the tracks electrically unless a considerable portion of the business is through passenger traffic.

It will pay all the large roads either to equip a number of their branches electrically or to control competing electric lines.

In order to remain on a dividend-paying basis it is imperative that most of the two-track lines either build additional tracks or control the electric railways that parallel them.

Believing that ultimately all of the traffic will be done by electricity, it is imperative that the managers of steam roads keep in touch with electrical progress.

Every system has its limitation. The electric is not exempt from this law, hence it will set forth what are well-known limitating laws concerning the transmission of energy.

The weight of copper necessary to transmit a given amount of power with a fixed loss will vary inversely as the square of the electro-motive force used.

The distance to which it can be transmitted with a given weight of conductor will vary directly as the pressure.

The distance to which it can be transmitted over a conductor with a given cross section will vary directly as the pressure.

The weight of copper necessary where the supply station is in the center of a system is only one-quarter that required if the station is at the end.

The weight of copper will vary inversely as the square of the number of supplying stations properly placed.

The electro-motive force required will vary inversely as the number of stations.

For terminal work in Chicago, for instance, three problems must be solved before electricity can be used for propulsion where the movement of trains is so large and the tracks so complicated.

An electric locomotive must be developed, of ample power, readily controllable and reliable in operation, and show a high economy. It must also have all the adjuncts necessary for train movement.

There must be a system of conductors and methods of supporting them, which can be relied upon for ample supply of current and absolute certainty of continuous contact at all speeds on curves, switches, cross-overs and the multitudinous combinations which exist on yard tracks.

There must likewise be a system of automatic block signaling, which while effective for steam traffic, will not be thrown out of operation by the use of tracks as conductors of electricity for a general supply. This is a more serious question than is at first considered, for this use will materially interfere with if not absolutely destroy the utility of what is known as the rail circuit system.

If railway managers were convinced that electricity would prove cheaper and safer, would increase the comfort of passengers, and render more rapid transit possible, a transformation of their lines would at once be undertaken; but they are not convinced, and will not be, until they learn the facts in their own way, and that is by going slowly, and trying branch lines, here and there, until they have obtained a sufficient amount of data from actual experience to dispel all doubt. When that point is reached the transformation will be rapid and the complete invasion of the steam railway field will take place at a pace equal, if not greater, than that of the street railways. And why should it not supersede steam if it has so many advantages. The railway companies are feeling the way.

Numerous interurban and suburban trolley roads have been completed recently and operated with almost phenomenal success. A well-built road of this kind, starting from a fair-sized city, owned and operated by a city company, and tributary to its system, connecting one or more thrifty villages with the city, will assuredly pay. Such a road cannot be too well built; the first cost is heavy, but in the end it will pay.

There is such a network of electric suburban lines surrounding Boston that it has even been found necessary to prepare a guide embracing the thirty-two roads in that territory. These roads use 4,232 motors, and their power stations have a capacity of 49,656 horse-power.

What has been the great effect of the introduction of electric traction? To the great mass of humanity it makes no small difference to gain a quarter of an hour, morning and evening, to go for one fare where formerly two were charged, or to find a new home as easy of access as the old one at a few dollars less per month. At first sight it is not altogether obvious how increased accessibility can depreciate property, either relatively or absolutely, yet sometimes it may be so. Take, for instance, a suburban region at or near the limit of convenient access by the horse cars. Under favorable circumstances it is likely to develop into a fine residence district, since it is most available to those whose hours of business are short or to those who keep carriages and can thus depend on somewhat unhandy steam service. The man who carries the dinner pail has to make his home nearer the city, where his long day will not be further lengthened by a protracted car ride. His home will, therefore, be found in the flats and tenements that skirt the city more closely. Now comes the electric car and pushes the half hour limit out a mile or two further. Gradually, but surely, working out across the dismal fringe that forms the back-yard of most cities, the man with the dinner pail, who appreciates a good situation as much as anybody, invades the new territory, and just so surely the man with the check book edges away toward regions less painfully accessible. In theory, we are a democratic people; in practice, as far from it as our means will permit.

Incidentally such an outward migration of population must have the effect of lessening the demand for accommodations in the belt from which the migration took place, unless the growth of population keeps pace with the increase of available living room, which it has not done in many instances.

Hence, until the inner area feels the effect of increasing demand for business purposes, it is likely to be at a disadvantage, temporary, it is true, but still existing. There may be, therefore, here and there traces of a decadent zone inside a zone of growth. In most cases it is not conspicuous, and it eventually works out its own salvation. There sometimes exist, however, fairly good residence areas which have managed to preserve something of their social integrity in spite of the inroads of cheap flats and tenements in their immediate neighborhood, perhaps on parallel streets. To such districts the coming of rapid transit may be the last straw. The surroundings deteriorate in response to the emigration outwards, and the last state of that street is worse than the first. There are other localities, less conspicuous, in which the same causes have accomplished similar results. Thence come, often enough, wails over the disaster brought by the deadly trolley. The trolley is not

at fault; it has simply hastened a little the progress of a perfectly natural urban evolution against which no protests avail.

One thing more must not be forgotten—the enormous total saving in time—the time available for human industry, or recreation.

Utilized for work or not, this time saved to the people has a human value for some good not incommensurate with its money value. Every change that lifts the burden of labor for even a few minutes per day is a gain on the whole for civilization, and the reclaiming of waste time is of social importance far greater than reclaiming waste land, in that it deals more directly with all people in all places.

DISCUSSION ON MR. BARRINGTON'S PAPER ON "ELECTRIC TRACTION."

By John F. Wallace.

(*Read at Meeting of Western Society of Engineers, December 2nd, 1896.*)

Mr. Barrington's paper on Electric Traction presents a great many points of interest, and will bring into the transactions of our Society much valuable information.

It will be readily seen that the writer looks at this question from the standpoint of the advisability of considering the substitution of electric power for steam; and while the paper under discussion treats exhaustively of the question of substituting electric power for horse or cable power, the question which seems most important to the writer, viz., the use of electricity instead of steam for handling modern railroad or suburban traffic does not appear to have been touched upon. This is probably due to the fact that applications of this kind are yet in their infancy.

Treating the question of the substitution of one power for the other, while electric power may be deemed more desirable for various reasons that cannot be demonstrated by dollars and cents, still the main underlying feature must, after all, be that of economy. The problem which the railroad manager has to face in considering this matter is, will the interest on the cost of the construction of the new application, plus operating and maintenance charges, be less than the cost of steam power plus operation and maintenance expenses. In considering any individual application, while the question might be answered in favor of electricity on a new installation, the problem is complicated by the difficulty of making satisfactory disposition of the existing steam plants with which suburban railroad lines are now equipped. When it comes to sacrificing the value of the present property, the cost of an electrical application is much enhanced.

One of the main deterrent elements is also the rapid advancement made in electric appliances, and the airy way in which electrical engineers as a rule speak of new and possible discoveries compels conservative railroad men to hesitate about adopting any one of the existing systems of electric transportation, for fear that in a short time better and more economical systems may be introduced. Conservatism and the inertia of invested capital are in a large measure the foundation rock upon which dividend-paying railroads are built.

So far the field for the use of electric traction on short lines of street railways has been so large that it has seemingly occupied the full capacity of electric engineers and electric companies, so that it has not been necessary for them to turn their attention to the substitution of electric power for steam on the older railroad systems, even for suburban applications. The problem consequently, so far as this branch of the question is concerned, has been practically neglected and is yet in a large measure unsolved. The writer does not understand that any application has been long enough in use to determine all the elements of cost that enter into the adoption of electric traction, in order that careful comparisons may be made with the well-known elements of cost surrounding the use of steam. Sufficient data also has not been obtained to enable railroad men to arrive at a definite opinion as to what system of electric transportation is best; whether it is better to use large, powerful, independent motors hauling trailers, or whether it is better to use combination motor and passenger cars with a larger number of transportation units. While on lines of light and regular traffic motor cars, which carry from 75 to 100 passengers and leave at frequent intervals may fulfill the requirements of that business, on the other hand this business may be so heavy and irregular that units of this character running even one minute apart may not be able to properly take care of it; or, the requirements of speed may be such that it would not be safe to run the small units of transportation so close together. Therefore the use of transportation units that would enable from 500 to 1,000 passengers to be carried on each train, leaving at slightly longer intervals during the busy hours of the day, might be absolutely essential.

A number of railroads having a large suburban business have been watching the development of electric traction for years, and there is but little question that they would be willing to substitute this power for steam if the questions that suggest themselves to railroad managers could be accurately and satisfactorily answered.

In reference to special applications, probably the railroad most favorably situated for the adoption of electric power for handling its heavy suburban traffic, is the Illinois Central Railroad. The conditions are about as follows:

The Illinois Central has a double track system between Randolph street and Grand Crossing, a distance of 9.29 miles, over which what is called the regular suburban service is handled. This service is carried on from 5 a. m. until 12:30 midnight, the intervals between trains varying from twenty minutes apart during the

light hours of traffic to five minutes apart during the hours of heavy business in the morning and evening; the number of cars in each train varying from four to eight, according to the demands of the business. The capacity of these cars is on an average fifty-six (56) seated and one hundred (100) sitting and standing. What is known as the express suburban service uses the regular suburban tracks from Randolph to Van Buren street, then branches off on independent double tracks passing east of the other Illinois Central tracks and reaching to Sixty-seventh street, trains in this service making no stops between Van Buren and Fifty-third streets, and attaining a speed between these points of approximately fifty miles an hour. At Sixty-seventh street the express trains are diverted, part to South Chicago, a distance of 12.72 miles from Randolph street; part continuing south on the main line to Homewood, 23.33 miles from the city, some stopping at Kensington, 14.35 miles, and some at Harvey, 19.86 miles: a certain number also branching off to Blue Island, a distance of 18.75 miles. These express trains run from 7 a. m. to 7 p. m., the service prior to and subsequent to these hours being taken care of on the regular suburban tracks. On the regular suburban tracks the stops average about 2,000 feet apart. North of Seventieth street, 8.57 miles from the city, there are no grade crossings, the tracks and right of way being protected by fences and walls in such a manner as to be admirably fitted for the introduction of the most economical system of electric transportation that may be devised.

Various problems come up for consideration: Whether or not it would be advisable to adopt electric power on any part or all of this system; the relative economies of the use of steam or electricity in this application; the proper location of the power house; the form, size and frequency of the transportation units. These and other problems in connection with this question would naturally cause the railroad manager to hesitate and consider long and carefully before taking any forward step of an experimental nature. While it is true that the substitution of electricity for horse, mule or cable power is decidedly advantageous, both as to desirability, and economy, it is not yet so apparent that its substitution for steam power is equally desirable and economical.

The writer of the original paper hinted at a few foundation principles which may be formulated in the general proposition that the field for electric power lies where the service to be performed consists of small and frequent units of transportation, moved over short distances; and that steam is more desirable for large and heavy units of transportation, moved infrequently over long distances and at high speeds.

The general question is one that presents many attractive features and is worthy of full and exhaustive treatment. It is to be hoped that a frank discussion of the original paper by both electrical experts and railroad engineers may be brought out. The suggestion is made to the Society that these papers be continued, and that both the original paper and the discussion developing here to-night be printed and furnished not only to members of our

Society who might care to follow the matter up, but also to electrical engineers and experts engaged in the business of manufacturing and installing electric plants, in order that the society may have the benefit of a full and free discussion of the subject.

DISCUSSION.

The paper by Mr. Edward Barrington on Electric Traction opens up a very interesting field for discussion.

Five years ago, when the Illinois Central Railroad Company had under discussion the substitution of electric for steam power for handling their suburban business, the writer made a number of comparative estimates with a view to determining the relative economy of the two systems; these estimates were based upon data obtained from all the then existing large manufacturers of electric motors, and the whole subject was treated as exhaustively as possible. The estimates were necessarily approximations; at that time no motors were being manufactured which were anywhere nearly large enough to do the work required for this suburban service, and necessarily the cost of construction and operation was somewhat difficult to determine.

The writer presents herewith nine sheets of tabular statements showing the estimated cost and expense of operation for electric equipment calculated to handle from 12,000 to 24,000 passengers per hour for World's Fair traffic, also an estimate for handling the regular Illinois Central suburban business by electric power, together with a comparative estimate on handling the latter by steam power.

Undoubtedly, with the rapid advance which has been made within the last five years, the figures given in these estimates would now be materially changed. The writer presents the estimates as a matter of history to preserve a record of the conditions existing five years ago, and also with a hope that some member of the Society, who is familiar with the most recent improvements, may be interested to show how great a saving may be effected as the result of the latest inventions in electrical science.

H. W. PARKHURST.

CHICAGO, November 30, 1896.

ESTIMATE No. 1.

Estimate on Electric Plant Equipment for the World's Fair Traffic, I. C. R. R., January, 1892.

Note.—This estimate is based on carrying 12,000 per hour, in 4-car trains; 7½ miles of track; speed, 20 miles per hour; 2 minutes headway; loops at ends of lines.

Plant. 3,600-H.P., including everything, at......$	91.00		$327,600
Running expenses per day:			
Interest, at 6 per cent. $19.656 per year; per day..	53.90		
Maintenance and taxes, 5 per cent. per year; per day..	44.90		
Coal, 54 000-H.P. hours, at 3 lbs , $1.00 per ton...	81.00		
Oil and waste................................	2.00		
Labor, 2 superintendents, prin. and ass't.......	16.00		
2 engineers, at $4.00..................	8.00		
4 oilers, at $2.00......................	8.00		
8 firemen, at $2.00....................	16.00		
2 dynamo men, at $3.00................	6.00	$235.80	
Line. Estimated at $1,300 per motor running, 30 motors.....			$39,000
Running expenses per day:			
Interest at 6 per cent. $2,340 per year; per day	6.40		
Labor, 1 foreman at $2.50, 4 linemen at $1.75	9.50		
Supplies, &c................................	1.00	$16.90	
Motors. Thirty running regularly, 10 per cent. reserve, 33, at $5.500..........			$181.500
Running expenses per day:			
Interest at 6 per cent., $10,890 per year; per day	$29.80		
Maintenance and taxes at 10 per cent. per day	49.70		
Labor, 60 drivers at $2.50 per day of 9 hours....	150.00		
Grease and waste.....	7.50	$237.00	
Cars. Including motor cars, 120+10 per cent. reserve 132 at $2,000.........................			$264,000
Running expenses per day:			
Interest at 6 per cent., $15,840 per year; per day	$43.40		
Maintenance and taxes, 10 per cent. per year; per day..................	72.30		
Labor—30 conductors, at $2.25.................	67.50		
" 30 brakemen, at $1.75.................	52.50		
Grease and waste.............	25.00	$260.70	
Total capital invested.............................			$812,000
Daily running expenses......................		$750.40	

ESTIMATE No. 2.

Estimate on Electric Plant Equipment for World's Fair Traffic, I. C. R. R., January, 1892.

Note.—Estimate is based on carrying 18,000 per hour; 4-car trains; 7½ miles of line; speed, 20 miles per hour; 1½ min. headway; trains turn on loops at ends of line.

Plant. 54,000-H.P. including everything, at	$91.00		$491,490
Running expenses per day:			
Interest at 6 per cent., $29,484 per year; per day,	80.10		
Maintenance and taxes, 5 per cent. per year; per day	67.30		
Coal 81,000-H.P. hours, at 3 lbs, at $1 per ton	121.50		
Labor, 2 superintendents, prin. and ass't	16.00		
2 engineers, at $4.00	8.00		
4 oilers, at $2.00	8.00		
8 firemen, $2.00	16.00		
2 dynamo men, at $3.00	6.00		
Oil and waste	2.50	$325.40	
Line. Estimated at $13.00 per motor running (45)			$58.500
Running expenses per day:			
Interest at 6 per cent., $3,510 per year, or per day	$ 9.60		
Labor-foreman, $2.50, 5 men at $1.75	11.25		
Supplies, &c	1.00	$21.85	
Motors. 45 running regularly, 10 per cent excess, say 50, at	$5,500 00		$275,000
Running expenses per day:			
Interest at 6 per cent., $16,500 per year, or per day	45.20		
Maintenance and taxes 10 per cent. per year, or per day	75.30		
Labor, 90 drivers, at $2 50 per day of 9 hours..	225.00		
Grease and waste	11.25	$356.75	
Cars. Including motor cars, 180+10 per cent. reserves 198. at $2,000			$396,000
Running expenses per day:			
Interest 6 per cent., $23,760 per year, or per day	$ 65.10		
Maintenance and taxes, 10 per cent. per year, or per day	108.50		
Labor—45 conductors, at $2.25	101.25		
" 45 brakemen, at $1.75	78.75		
Grease and waste	37.50	$391.10	
Total capital invested			$1,220,900
Daily running expenses		$1,095.10	

ESTIMATE No. 3.

Estimate on Electric Plant Equipment for World's Fair Traffic, I. C. R. R., January, 1892.

Estimate based on carrying 24,000 per hour, 4-car trains, 7½ miles of line; speed, 20 miles per hour; 1 minute headway; trains turn on loops at both ends.

PLANT. 7200 H. P., including everything.....$ 91 00			$ 655,200
Running expenses per day:			
Interest at 6 per cent., $39,312 per year; per day	107 70		
Maintenance and taxes at 5 per cent. per year; per day	89 70		
Coal, 108,000 H. P. hours, at 3lbs. at $1 per ton	162 00		
Oil and waste	4 00		
Labor—2 superintendents; 1 prin., 1 assist.	16 00		
" 2 engineers at $4.00	8 00		
" 6 oilers at $2.00	12 00		
" 12 firemen at $2.00	24 00		
" 3 dynamo men at $3.00	9 00		
		$ 432 40	
LINE. Estim't'd at $1,300 per motor running (60)			78,000
Running expenses per day:			
Interest at 6 per cent, $4,680 per year; per day	$ 12 80		
Maintenance and taxes at 10 per cent. per year; per day	14 75		
Supplies	1 50		
		29 05	
MOTORS. Sixty running regularly, + 10 per cent. excess, 66 at $5,500			363,000
Running expenses per day:			
Interest at 6 per cent per year, $21,780; per day	59 70		
Maintenance and taxes at 10 per cent. per day	99 40		
Labor, 120 drivers at $2.50 per 9 hours	300 00		
Grease and waste	15 00		
		474 10	
CARS. Including motor cars, 240 + 10 per cent. reserve, 264, at $2,000			528,000
Running expenses per day:			
Interest at 6 per cent., $31,680 per year; per day	86 80		
Maintenance and taxes, 10 per cent. per year; per day	144 60		
Labor—60 conductors at $2.25	135 00		
" 60 brakemen at $1.75	105 00		
Grease and waste	50 00		
		521 40	
Total capital invested			$1,624,200
Daily running expenses		$1,456 95	

ESTIMATE No. 4.

Estimate on Electric Plant Equipment for World's Fair Traffic, I. C. R. R., January, 1892.

Note.—This estimate is based on carrying passengers at the rate of 12,000 per hour between 6 a. m. and 3 p. m., and between 7 and 12 p. m.; at the rate of 18,000 per hour between 3 and 5 p. m., and at the rate of 24,000 per hour between 5 and 7 p. m.; line 7½ miles long; trains, 4 cars each; speed, 20 miles per hour; headway, 2 minutes, 1½ minutes, and 1 minute; trains turn on loops at ends.

Plant. For maximum of 60 trains per hour, 7,200 H. P., at	$ 91 00		$ 655,200
Running expenses per day:			
Interest at 6 per cent., $39,312 per year; per day	107 70		
Maintenance and taxes at 5 per cent. per year; per day	89 70		
Coal, 63,000 H. P. hours, at 3 lbs ; at $1.00 per ton	94 50		
Oil and waste	3 00		
Labor—2 superintendents, prin. and assist.	16 00		
" 2 engineers at $4.00	8 00		
" 4 oilers at $2.00	8 00		
" 8 firemen at $2.00	16 00		
" 2 dynamo men at $3.00	6 00		
		$ 348 90	
Line. Estimated at $1,300 per motor running, maximum 60			78,000
Running expenses per day:			
Interest at 6 per cent., $4,680 per year; per day	12 80		
Labor—Foreman at $2.50, 6 linemen at $1.75	13 00		
Supplies	1 50		
		27 30	
Motors. Maximum required, 60—say 62—at $5,500			341,000
Running expenses per day:			
Interest at 6 per cent., $20,460 per year; per day	56 10		
Maintenance and taxes at 10 per cent. per year; per day	93 40		
Labor—70 drivers at $2.50 per 9-hour day	175 00		
Grease and waste	10 00		
		334 50	
Cars. Maximum number needed, 240 — say 245—at $2,000			490,000
Running expenses per day:			
Interest at 6 per cent., $29,400 per year; per day	80 60		
Maintenance and taxes at 10 per cent. per year; per day	134 30		
Labor—35 conductors at $2.25	78 75		
" 35 brakemen at $1.75	61 25		
Grease and waste	40 00		
		394 90	
Total capital invested			$1,564,200
Daily running expenses		$1,105 60	

TABULAR COMPARISON OF ESTIMATES 1 TO 4 ON ELECTRIC PLANT FOR WORLD'S FAIR TRAFFIC, I. C. R. R.

NOTE—This is based on assumption of 15 miles per round trip per train, and on the assumption in the first three estimates that trains carry full loads six hours, and half loads the remaining twelve hours.

Running Expenses per Train Mile.

	1.	2.	3.	4.
Plant (Central	.0291	.0268	.0267	.0369
Line	.0021	.0017	.0017	.0027
Motors	.0293	.0294	.0293	.0354
Cars	.0322	.0322	.0322	.0424
Totals	.0927	.0901	.0899	.1174

Running Expenses per Car Mile.

	1.	2.	3.	4.
Plant (Central)	.0073	.0067	.0067	.0092
Line	.0005	.0004	.0004	.0007
Motors	.0073	.0073	.0073	.0088
Cars	.0080	.0080	.0080	.0106
Totals	.0231	.0224	.0224	.0293

Running Expenses per Passenger Mile

	1.	2.	3.	4.
Plant (Central)	.000109	.000100	.000100	.000092
Line.	.000007	.000006	.000006	.000007
Motors	.000110	.000110	.000110	.000088
Cars	000121	.000120	.000118	.000104
Totals	.000347	.000336	.000334	.000291

ESTIMATE ON STEAM EQUIPMENT FOR SUBURBAN SERVICE ILL. CENTRAL RAILROAD, JANUARY, 1892.

This is made up for Comparison with Estimate on page 778 of same date, for Electric Equipment for same service.

The train assumed is 1 engine and 6 cars, each seating 50.

MOTIVE POWER. 60 engines, at $8 400			$504,000
Daily expenses:			
Interest at 6 per cent., $30,240 per year, or per day	$ 82.90		
For an average of 12 hours of 4,000 per hour each way, there would be on the main line 2,688 engine miles. On the So. Chicago branch, for an average of 12 hours of 2,000 per hour each way, there would be 800 engine miles, and on the Homewood extension there would be 2,384 engine miles. Total 5,872 engine miles, actual cost 15.58 cents	914.86	$997.76	
CARS. Of present style 360, at $3,000			$1,080,000
Daily expenses.			
Interest, at 6 per cent , $64,800 per year, or per day	175.50		
Expense for past year was at rate of $2.3867 per car; 360 cars, at $2.3867	859.20	$1,034.70	
Total capital invested			$1,584,000
Daily expense		$2,032.46	

TABULAR COMPARATIVE STATEMENT OF ESTIMATED COST AND RUNNING EXPENSES FOR ELECTRIC EQUIPMENT FOR I. C. R. R. FOR WORLD'S FAIR TRAFFIC.

	12,000 PER HOUR.		18,000 PER HOUR.		24,000 PER HOUR.		COMBINED PLAN.	
Central Plant	$327,600		$491,400		$655,200		$655,200	
Daily Expense		$235.80		$325.40		$432.40		$348.90
Line	39,000		58,500		78,000		78,000	
Daily Expense		16.90		21.85		29.05		27.30
Motors	181,500		275,000		363,000		341,000	
Daily Expense		237.00		356.75		474.10		334.50
Total Motive Power	$548,100		$824,900		$1.096,200		$1,074,200	
Daily Expense		489.70		704.00		935.55		710.70
Car Service	264,000		396,000		528,000		490,000	
Daily Expense		260.70		391.10		521.40		394.90
Grand Totals	$812, 00		$1,220,900		$1,624,200		$1,564,200	
Daily Expense		$750.40		$1,095.10		$1,456.95		$1,105.60

Running Expenses per Train Mile

Central Power	.0291		.0268		.0267		.0369	
Line	.0021		.0017		.0017		.0027	
Motors	.0293	.0605	.0294	.0579	.0293	.0577	.0354	.0750
Cars		.0322		.0322		.0322		.0424
Totals		.0927		.0901		.0899		.1174

Running Expenses per Car Mile.

Central Power	.0073		.0067		.0067		.0092	
Line	.0005		.0004		.0004		.0007	
Motors	.0073	.0151	.0073	.0144	.0073	.0144	.0088	.0187
Cars		.0080		.0080		.0080		.0106
Totals		.0231		.0224		.0224		.0293

Running Expenses per Passenger Mile.

Central Power	.000109		.000100		.000100		.000092	
Line	.000007		.000006		.000006		.000007	
Motors	.000110	.000226	.000110	.000216	.000110	.000216	.000088	.000187
Cars		.000121		.000120		.000118		.000104
Totals		.000347		.000336		.000334		.000291

Estimate on Electric Equipment for the Suburban Service, I. C. R. R., January, 1892.

CENTRAL PLANT. Including buildings, boilers, engines, pumps, generators, etc., etc., 7,500 H. P., at		$ 91 00		$ 682,500
Daily expenses:				
Interest at 6 per cent., $40,950 per year, or per day		109 40		
Maintenance, 5 per cent. per year; per day		91 20		
Coal for 75,000 H. P. hours at 3½ lbs., at $1.00 per ton		131 25		
Oil and waste		3 50		
Labor—Superintendent	$10 00			
" Assistant "	6 00			
" Chief engineer	5 00			
" 3 assist. " at $4 00	12 00			
" 4 oilers at $2.00	8 00			
" 4 dynamo men at $3.00	12 00			
" 12 firemen at $2.00	24 00			
" 12 coal wheelers at $1.50	18 00	95 00		
			430 25	
TROLLEY LINE AND FEED WIRES				325,000
Daily expenses:				
Interest at 6 per cent., $19,500 per year, or per day		53 40		
Repairs, labor, etc., at 5 per cent. per year, or per day		44 50		
			97 90	
MOTORS. Sixty motors at $6,000 each				360,000
Daily expenses:				
Interest at 6 per cent., $21,600 per year, or per day		59 20		
Maintenance at 10 per cent. per year, or per day		98 60		
Labor, 60 drivers at $3.25 per 12 hours		195 00		
Grease and waste		15 00		
			367 80	
CARS. Including those carrying motors, 240, at $2,000				480,000
Daily expenses:				
Interest at 6 per cent., $28,800 per year, or per day		76 20		
Maintenance at 10 per cent. per year, or per day		131 50		
Labor, 240 men at $2.75 per 12 hours		660 00		
Grease and waste		50 00		
			917 70	
Total capital invested				$1,847,500
Daily expense, including interest			$1,813 75	

COMPARATIVE STATEMENT OF COST OF SUBURBAN SERVICE, I. C. R. R., BY STEAM AND BY ELECTRIC EQUIPMENTS.

January 29, 1892.

	ELECTRIC EQUIPMENT.		STEAM EQUIPMENT.	
	With Interest.	Without Interest.	With Interest.	Without Interest
Central plant	$ 682,500	....	....	....
Daily expenses	$ 430 35	$ 320 95	....	....
Trolley and feed wires	325,000	....	....	....
Daily expenses	97 90	44 50	....	....
Motors (60)	360,000	....	....	....
Daily expenses	367 80	308 60	....	....
Total motive power	$1,367,500	....	....	....
Daily expenses	$ 896 05	$ 674 05	....	....
Motive power	....	....	$ 504,000	....
Daily expenses	....	....	$ 997 76	$ 914 86
Car service	$ 480,000	....	1,080,000	....
Daily expenses	$ 917 70	841 50	1,034 70	859 20
Total capital	$1,847,500	....	$1,584,000	....
Daily expenses	$1,813 75	$ 1,515 55	$2,032 46	$1,774 06

Running Expenses per Train Mile.

Motive power	$ .1526	$ .1148	$ .1699	$ .1558
Car service	.1563	.1433	.1762	.1463
Totals	$ .3089	$ .2581	$ .3461	$ .3021

Running Expenses per Car Mile.

Motive power	$ .0381	$ .0287	$ .0283	$ .0260
Car service	.0391	.0358	.0294	.0244
Totals	$ .0772	$ .0645	$ .0577	$ 0504

Running Expenses per Passenger Mile.
(Estimated 880,000 passenger miles.)

Motive power	$.001017	$.000766	$ 001134	$.001040
Car service	.001043	.000956	.001176	.000976
Totals	$.002060	$.001722	$ .002310	$. 002016

The last table is based on an assumption that the average traffic is one-half the maximum capacity.

DISCUSSION.

Mr. Brinckerhoff: Mr. Barrington has gone very fully over the subject and touched on nearly every form of electric traction which we now have in actual use, so that it is rather difficult to bring up anything new, but there are some points that I have made a few notes on that possibly might be of interest.

On page 8 there is a remark in quotations gathered from the Daily Press which gives a rather typical way of expressing the deadly trolley idea. The wording is: "A system less noisy, less unsightly, less dangerous, and more economical in operation, while still as rapid as the one now in use is greatly to be desired." That evidently is a very strong point, but it would lead us to believe that the trolley was responsible on account of some inherent quality for the accidents that are laid at its door. The fact is that in most cities where trolleys have been introduced they have been the first form of transportation to give increased speed over the horse car. This fact has led to the cry against the deadly trolley. Statistics compiled from the accident reports of the largest trolley systems in the country show that not more than one accident in eight or nine hundred were due to the trolley proper—that is, the shock from the current wires or collision with poles, the remainder being due rather to the speed at which cars were operated on crowded thoroughfares. Had compressed air, storage battery or any other form of motive power been put in the same position we would have had the same result. The fault lies not in the system, but in the license that has been allowed the companies in running their cars at full speed in the heart of the city. The fact that a motorman has the power to run his car up to full speed in the crowded districts as well as in the suburbs is no excuse for allowing him to do so. With proper discipline the speed of the trolley car can be regulated in certain districts, just as is that of the cable car, but the demand for this must come from the public. As long as they allow the street to be used for high speed rapid transit lines, it matters little what is the form of the motive power. Given a certain speed, a certain number of accidents will occur on an average. Place certain restrictions as to the speed of cars and enforce these restrictions and it will undoubtedly reduce this cry of "deadly trolley."

In the matter of poles and wires, it is undeniable that they are unsightly and a hindrance to the fire department, but it seems to me that it is just to give the devil his due and condemn them on these particular grounds and not deceive ourselves in the idea that by the substitution of some other form, such as compressed air, we would get any different result from a high speed car on a crowded thoroughfare.

Another point, which comes nearer to one we are particularly interested in to-night, is the mention of a proposed system for Manhattan Elevated. The author says: "The third rail system will probably be used in connection with storage batteries as an auxil-

iary in case of accident. Now this would rather convey the impression that the power stations as installed and operated in connection with the third rail system are so unreliable that it is advisable to have some emergency apparatus to keep the trains moving. I had occasion to look over the record of our Metropolitan for another purpose and incidentally I discovered in adding it up that the total sum of delays amounted in the past six months to seven minutes, that is, due strictly to failure in power station machinery. That is an average of 1.15 minutes per month, or 2.1 seconds per day. Now that shows that we lose less time from this cause than we often do by some fussy person who is afraid of getting on the wrong train.

In the next paragraph I note the statement that these storage batteries that are contemplated are capable of propelling a locomotive at 15 or 20 miles per hour for a distance of about 36 miles. This is at the top of page 9. Now I supposed Mr. Barrington would be here. I would like to have asked him a question as to whether he means literally that this would haul simply the locomotive. In that case it would run only six hundred feet before it would come in contact with the previous train and would be really no use in keeping the service running. On the other hand, if the batteries are capable of hauling a train of six or eight cars the distance of thirty-six miles at such a speed, such figures as I have from battery people would make the cost of such a battery amount to about $15,000 per locomotive and that seems to me rather an expensive emergency apparatus. I do not want to be understood as objecting to storage batteries as storage batteries, but to this method of using them. The use of storage batteries to reduce the fluctuations in load and save the strains of the generating plant is very attractive especially to railway men, who have to contend with probably greater fluctuations in load than occur in any other application of electricity, but I have not yet been able to see clearly the advantage of hauling this dead weight up and down the line when the same results can be obtained from a stationary battery of much smaller size and suitably located.

There is a general summing up on page 21 in which the author states his idea of the requirements for terminal work in Chicago (by terminal work I presume he means the handling of the business of some of our large roads). It strikes me that without going very far we can find in operation apparatus that is every day meeting successfully very nearly these requirements. For instance we have the Baltimore and Ohio tunnel locomotives which answer all requirements which he suggests, with the single exception of economy and this is due to the fact in that particular case that only one or two of the locomotives operate at the same time. If these large units formed only a portion of the load, the bulk of it coming from smaller suburban units, such as we would have on local service, the economy would be fairly high. For the light passenger service a

simple enlargement of the various parts that are now used on our elevated roads would handle the trains required in that service and these we can see are operated successfully every day.

The second point raised is as to a system of conductors. I think an examination of the third rail system of the Metropolitan will show that we have handled the question of continuous contact in as complicated track layouts as occur in any surface work. I do not pretend to say that just as it stands this would make the ideal surface equipment, but I cannot see why we should feel that having gone so far successfully we need fear that surface railroad conditions will introduce complications that are beyond the ingenuity of man to overcome.

As to the system of automatic block signals, that is a serious matter. I can say, however, that we are operating at present a continuous block signal system with an independent wire circuit which does not conflict with our track return. These signals make about thirty-five thousand movements per day and are giving satisfactory service. The question of practicability of handling the suburban passenger service of some of the largest steam railroads coming into Chicago, is really not doubted by railway engineers and many of them would admit if they felt it policy to do so that they could operate cheaper with such an equipment. The most of them are, I should judge, in this position—they have now a large and expensive steam equipment which they would be obliged to discard, and until this must be renewed or they are forced to make a change by the competition of competing lines, they do not feel justified to go into such large expense. To my mind this question has ceased to be one of engineering, it is rather in the hands of the business managers, when they say the word the engineers I think can attend to the details without any very great departure from present methods.

The President: I would like to make a remark: that they will say the word the very moment that they can be satisfied by their engineers that the question of economy is an accomplished fact and not an experimental one.

Mr. Brinckerhoff: I would like to give you some figures on economy, but hardly feel free to do so.

The President: That is exactly what we want.

Mr. Brinckerhoff: Of course you understand my position as engineer in connection with an enterprise of that sort. It is hardly a subject that I can discuss for publication. I can say, however, that we have demonstrated to the other elevated roads that we are making a very considerable saving over steam. They have either changed or are contemplating changing their motive power.

The President: The road I am connected with has been following that question for years and it is simply a question of economy. Just as soon as that application can be proven to be more economical than some other, taking into consideration the plant that is now there, why then it will be used, we think, beyond any question, and that is the position that a great many railroad managers on other roads that I am acquainted with take on the question.

Mr. Brinckerhoff: I would be glad to give information, but I hardly feel prepared to do so off-hand.

Prof. Jackson: In the absence of Mr. Barrington I do not like to discuss this paper from a strictly technical standpoint. The author has evidently written the paper from the standpoint of a storage battery man and in my opinion gives undue weight to that form of apparatus.

The President: The rules of our society permit unlimited pitching in to the paper of any man, whether he is present or not.

Prof. Jackson: While a storage battery is a very valuable adjunct in many cases, it cannot be said to be the solution which removes all ills that the central station man finds himself heir to. The storage battery is valuable in many places, but the central station man must make his station operative of itself, before the storage battery will be of much service to him. That point, I think, is pretty fairly proven by experience.

Dropping that question, however, I want to call attention to the remark the author makes on page 2 in regard to the Ohio Legislature placing electric railways under the control of the State Railroad Commissioner. That is in the direct line of what is being followed in many other states, in fact the street railways have been for a long time under the control of the State Railway Commissioners in Massachusetts and New York and to a very limited extent under a similar control in Pennsylvania and elsewhere; and many of the states have passed special laws affecting electric railroad traction with a view of protecting the car traffic, protecting the occupancy of the streets by traffic outside of the cars and also protecting the motor-men themselves. Thus, for instance, we find in quite a number of states laws requiring that electric cars shall be vestibuled; in other words, that the motor-man on the electric car shall be protected from the weather, the idea being in this case that if the motor-man is protected from the weather he will be more alert and consequently more able to take care of the traffic which he hauls and also avoid difficulties with outside traffic. There is no question that electric street railroads have too much license in our cities. The danger from the deadly trolley has been due, with few exceptions, as has been pointed out by earlier speakers, to the fact that heavy, large cars carrying a great many passengers have been operated at undue rates of speed through crowded streets. The electric car has very decided advantages for suburban and semi-suburban traffic (that is, the traffic in the outlying residence districts of cities) from the fact that it can make fast time where the streets are clear of obstruction; it has also the advantage that it can make fast time between obstructions in crowded streets; it has the disadvantage that the motor-man can make fast time if he chooses where he has no business to run rapidly. In other words, where the cable is run in crowded streets, the cable itself runs slowly and the gripman is obliged to run his car slowly, while the motor-man on the trolley car can run at as fast speed in a crowded

street as in an unobstructed street and it is on account of this that we have had an extremely large number of accidents from the trolley.

Again (I am speaking of this particularly because the deadly trolley has been spoken of and I do not think that this side of the subject has heretofore been given a fair discussion, although it has been mentioned again and again in the Street Railway papers), the great number of accidents which have occurred in some of our cities, such as Brooklyn and Philadelphia, have occurred to a large extent within a comparatively short time after the electric cars were started in the various localities, and started at a fast speed. The electric cars in such cases have replaced slow moving horse cars; the people were not used to finding an electric car bearing down on them from half a block away in less time than they could cross the street and in many cases were caught, so that the cry of the deadly trolley is not a fair one to bring out against the overhead or underground trolley wire construction. That cry will hold with precisely the same force in case of operation of heavy, speedy cars by storage batteries or by compressed air motors.

The President: Mr. Barrington will have a chance to answer anything that is said, as the papers will be submitted to him before the matter is closed, so that you need not be timid on that account in discussing the paper freely.

Mr. Summers: I think I agree, Mr. Chairman, with your original statement, that the final solution resolves itself into the dollars and cents account, and I think that there is a more pronounced tendency to decry the professional man as simply a technical adviser, he must be a financial adviser as well. Prof. Unwin has said that an electrical engineer could accomplish almost anything in power transmission if you allowed him unlimited means.

There has been too much of a tendency in practice for the technical man to rush in without due regard to the financial aspects of the case. Mr. Barrington says that many of the roads now operated by horse can be advantageously transformed into electrical roads. The fact is that the best financial authorities say that there is hardly a road now operated by horse that can be transformed into an electrically operated road and make a satisfactory investment, while almost fifty per cent. of the roads in operation are not dividend paying roads. It is plain that any road whose net income or net profits does not exceed five thousand dollars a year is apt to have the whole year's profit wiped out by a single accident. Any road of that kind is not a widow and orphan investment fund.

The early tendency of the electric road promoter was to go into a town where the horse railroad had a franchise, make the change and attempt the operation of a heavy, self-propelling car on a roadbed that was designed for use with horses. This has led to almost all the earlier roads being reconstructed in order to obtain any satisfaction and a rail as heavy as is used on our heaviest railroads is now common practice.

I think Prof. Jackson has voiced my sentiments on the storage battery phase of the subject, as I quite agree with his expression and would criticise the statement that Mr. Barrington has made as to the advisability of substituting or of adding a storage battery to many of the central stations we have put in operation. It would be a station of peculiar situation or of considerable size that would warrant this investment.

Mr. Barrington takes an optimistic view of the underground trolley system and of the Tesla system. The Tesla system requires three wires for its operation; its only advantage is that it would permit the use of a high voltage and would be economical for country service or a service over long distances, but the necessity of having three connections, that is, two trolleys and a rail connection, or three separate trolleys, has prevented its being used so far, together with the fact that the motors have not been put upon the market for railway use, though experimental determinations have been made which would seem to indicate that they are entirely satisfactory. The underground conduit as originally put in in Chicago has proved to be a failure. I refer to the Love conduit at Fullerton Avenue. The experiments at Washington, both with the button system and the conduit system, cannot to my mind be accepted as representative experiments, for Washington might be said to be merely a village as compared with Chicago, and the experiments would hardly represent the practical conditions to be found in larger cities of the United States.

The cable system is unquestionably a satisfactory means of transportation for a crowded city district and has demonstrated that it is a dividend earner, though it costs three or four times the amount that the electrical equipment would. The necessity of putting in a heavy track construction in street railway service has run the cost of construction for electric systems up very high. An estimate of city construction for the city of Chicago would be something like $25,000.00 per mile for double track, not including electrical equipment, simply paving and track construction proper, the cable road costs from $50,000 to $100,000 for the same construction. The gain of course from the electric system is that a far greater percentage of the power is transmitted to the wheel of the car than in the cable. In the cable, as we all know, from 30 to 75 per cent. is used in hauling the cable, D. K. Clark estimating that it requires four to five horse-power for every 1,000 feet of cable, the cars requiring from three to four horse-power each.

The New York, New Haven & Hartford Railroad on their Nantasket Beach division in the summer of '95 equipped the division with electricity; they ran an average of 150 trains per day. They made, at that time, something of a radical departure in substituting the fig. 8 trolley wire, which has since been frequently used, the idea being to prevent any jumping of the trolley, which is one of the principal difficulties in high speed trolley service. The fact is quite significant that when they extended the service they used the third rail system, the rail was put in the center of the track; it cleared

the pilots about two and one-half inches. They found occasionally an engine would go over the road with some part hanging low, and the result was the electric trains stopped until the steam engine got off the section. In order that the short circuits occurring on this division would not affect the rest of the system a separate feeder system was used, equipped with magnetic circuit breakers. The third rail was discontinued at crossings and the current carried on by means of an insulated cable, the trains being carried over by momentum. There have been many suggestions made as to carrying a connection through the train and keeping one contact until the next is made. The third rail service system is entirely experimental and I do not think there is any evidence to show that it is as yet practicable.

The button system that Mr. Barrington refers to is an old system and is brought forward periodically under some slightly different guise. The general plan is to keep alive the rails immediately under the car and cut it out as the car leaves it, so that the whole track is dead except as the car passes over. Contact boxes are put from seven to 30 feet apart, so that every few feet of road you have a system of switches, either electrically or mechanically operated, which connect the section to the supply feeders, and thus pass the current up to the car, each section being alive wherever the car is on it. The system is experimental and there are no roads that have been in operation long enough to justify the assertion that it is practical as yet. The Baltimore & Ohio tunnel belt line, which is operated by electric locomotives of very large size, is giving satisfactory service, it is true, but I do not think the most enthusiastic advocate of electrical transmission can praise the aesthetic appearance of the structure. It reminds one of that Grand Avenue bridge, as it takes almost a suspension bridge construction to support the trolley conductor. Everyone can appreciate, however, what it means to carry the amount of current required and that a heavy structure is necessary.

The operation of the elevated roads here in Chicago, I suppose, is the nearest approximation to heavy electric motor service that we have had so far, and yet the ease with which you can operate the third rail on elevated structures is entirely a different problem from that the surface road presents.

Referring to Mr. Brinckerhoff's remarks, I hope that he will not consider the question that I may ask impertinent at all, but he gave a figure of seven minutes' delay in six months. The operation of the Metropolitan road has been watched with a great deal of interest, I think, by all engineers, and it is known that they have had two or three delays and I would like to ask whether the six months covered the period in which those delays took place? I do not make this inquiry in a criticising way at all, but simply to bring out a most important question, and that is, What size unit shall be used and what is advisable as well as economical?

Mr. Lundie: The general question of electric traction is a little ambiguous. Traction in its very nature is mechanical, and I simply

make this remark to lead on to the fact that this whole question is one of transmission of energy from a central power station. In a central power station, by using large units you can get out of a pound of coal a great many more foot pounds of energy than you get out of the same amount of coal out on the road in a locomotive. Mr. Barrington gives an illustration of a central station where 2.89 pounds of coal were required per electrical horse-power hour when the engines were running condensing as designed. When they were operated non-condensing, owing to the lack of water, they required 3.93 pounds of coal to produce the same energy. Say then that an average of 3.4 pounds of coal are required to develop an electrical horse-power hour. This would probably be equivalent to five pounds of this coal out on the road per brake horse-power hour. Now, then, let me quote from Mr. Goss' experiments on his locomotive at Perdue. These are probably as reliable experiments as we have. Mr. Goss, out of a series of twenty tests, gives an average of 5.3 pounds coal actually used per indicated horse-power hour. We may then figure on six and one-half pounds of coal developing a horse-power hour at the rim of the wheel, so that you have five pounds in one case and six and one-half in another, or one and one-half pounds saving in favor of the central station. Against this pound and a half you have to consider the capital invested in the power house, and the transmission system. You must also take into account the depreciation in the transmission system. I would like to ask those gentlemen who are more directly posted on electrical appliances for some figures on economy. We have no Niagara Falls here, we depend on coal for producing energy. How much energy can you get out of a pound of a given quality of coal by the different systems of producing traction?

The President: There is one gentleman here who is very much interested and reference has been made to the company he represents, Mr. Coster, manager of the Chicago Agency of the Westinghouse Electric and Manufacturing Company.

Mr. Coster: I only wish to say a few words; I am not going to discuss Mr. Barrington's paper, but I am desirous of giving a few facts which I just penciled out while listening to some of the discussions. I think you are right, Mr. President, in your opening remarks when you said that if the electric companies could prove to the railway companies that there was economy in installing an electric plant to take the place of the steam plant, that they would do so. Now let us take, for instance, the Illinois Central Railway, which is very near to our hearts, as we all use it very often. They have a very excellent locomotive equipment for their suburban service. This equipment, I suppose, cost a good deal of money; if they were to do away with this equipment and replace it by electric power, I suppose the locomotives could not be used for their cross-country service. In that case the electric companies would be at a disadvantage, and I do not blame the Illinois Central for not substituting electric traction at the present time, for it would not pay them as long as

they had these elegant locomotives. They will have to be worn out first. If, on the other hand, the Illinois Central Railroad were equipping their road afresh to-day, I am sure that several companies could demonstrate to their satisfaction that they could operate their road cheaper by electricity than by steam. That is, not the entire road, but only the suburban traffic of their road.

Now I would like to ask a question of some superintendent of motive power, if there is one here, or master mechanic, who has probably taken indicator cards on locomotives. Can they give me an idea of what it costs to produce a brake horse-power with an average good locomotive? I mean the cost in dollars and cents for fuel; let us get at that. Can any one answer that question?

Mr. Lundie: I think that is answered by the extract here from Mr. Goss' paper. Here are twenty experiments and there is an average of five and three-tenths pounds of coal per indicator horse-power per hour. In another part of this paper you will find he gives a fluctuation of something like 15 to 17 per cent, so I figured out about six and one-half pounds of coal to brake horse-power hour. I think that is probably not far out of the way, at least considering his figure as given here.

Mr. Coster: The point I desire to make is this. We listened to Mr. Brinckerhoff's statements and they were very interesting, especially because Mr. Brinckerhoff is not connected with any electrical manufacturing establishment and never has been, so I understand. He spoke as an engineer who has been operating railways. There is no doubt that electricity has succeeded on the elevated roads in Chicago, for if it had not, the very able financiers connected with those roads would not decide on a change. But this is the point which I would like to make, namely, that a brake electric horse-power can be produced by the motor of a locomotive for one hour for something like two-tenths of a cent for fuel. Now any number of companies would guarantee to produce these results. In addition, the attendance on electric roads would naturally be less than the expense of railway engineers and firemen. The point can easily be settled by every one present here that with a steam locomotive you cannot produce better results than that. The matter of economy taken as a whole must be determined by local conditions, and I think our President is quite right to say that it would not be economy for his road to adopt an electric system, for it is very hard to produce this economy until they have worn out their elegant suburban steam equipment.

The President: There is one thing that I think is conceded except by electric engineers, and that is that the modern steam locomotive engine is the most economical generator of power as applied to draw-bar pull, or ability to pull a train, that there is in existence at the present day.

Mr. Bley: I would like to ask a question or two that occurred to me. In regard to the accidents that occur in connection with the trolley, what is the relative weight of the cars representing the hauling of the same number of passengers as with the cable for elec-

tric motor and for storage battery. The point is this, the lighter a car is for the same number of passengers, the less the liability of accident because of the ability to stop a car sooner, and I think that this has an important bearing on the question of main city traffic.

The President: I would like to make an apology to the society, or rather, my conscience is somewhat hurting me; I have rather encouraged this discussion for some length, for the reason that I take a train at 2:30 and time is no object. The other members may not feel that way, and if they desire to stop discussion a motion will be in order.

Mr. Gerber: Inasmuch as there is no very great desire to adjourn, I would like to ask one question. On page 14 Mr. Barrington states that the draw-bar pull on the Baltimore & Ohio Railway is 63,000 pounds. What is the ratio between the weight of the locomotive and the draw-bar pull?

The President: I presume that some gentleman that is up on ratios will answer that question between now and next Wednesday night.

Mr. Lundie: I think that ought to be about 15 per cent. of the weight of the locomotive.

Mr. Gerber: Pretty heavy locomotive, 420,000 pounds.

Mr. Lundie: Perhaps a pretty heavy draw-bar pull.

The President: Mr. Morison, cannot you favor us with something?

Mr. Morison: I came here to learn rather than to speak. I do not know that there is anything that I can say which will at all add to the value of the discussion already had. There is one point which already belongs in this paper, but which might have an influence on the use of electric traction on general railroads. There are special locations where on concentrated grades the same combination making the concentrated grade—hauling up steep valleys—gives opportunity for water-power, and the advantages of using electric power as an assistance on heavy grades I have never seen discussed, but it seems to me it is to be considered in a great many cases.

Mr. Bley: I have not heard any answer to my question as to the relative weight of cars representing the different methods of traffic, and so I will venture another question. The statement is made, I believe, by Prof. Jackson, that storage batteries cannot be used in initial installations. Now I am not very well posted on electric matters and I would like to know why that is. I do not see why that cannot be considered.

Prof. Jackson: My statement was misunderstood. My statement was that if a plant would not work satisfactorily without the storage battery, if the plant could not be operated of itself, the storage battery would not cure all its ills. That the plant must be one that could be operated without the storage battery and then the battery in some cases may add some economy.

Mr. Bley: Why is it?

Prof. Jackson: Because it is not a producer of power; it is a waster of power and a waster of money on account of its maintenance.

Mr. Bley: According to Mr. Barrington it is a saver of power, as he certainly suggests.

Prof. Jackson: It is in some cases a saver of expense on account of steadying the load.

The President: To a man that has no electrical knowledge to speak of, it does not seem that anything that you have got to pump power into and then pump it out of it and take it out again can be economical in comparison with the direct manufacture of power.

Mr. Bley: Don't you do that when when you pump your water into the boiler?

The President: But you do not do it in that way; you do not pump in the water without doing something to it.

Mr. Summers: I think the question can be more simply put by assuming that it is not so much the gain in the electric power itself, it is diminishing the mechanical losses. If you put in a storage battery and supply it power, the fixed station loss would be a small part of the total power generated. For that reason the storage battery is a desirable auxiliary to the station. The stand-by (?) losses of a steam plant are very large, radiation, leakage, condensation, etc. You have to be prepared to supply your customers at all times, and these losses are what eat up the profits. In street railway traffic you have two peaks to your load. It starts at 5:30 in the morning and rises to a peak at about 8 o'clock and falls off again. That is, the valley between the two peaks; then it starts to rise again at 5 o'clock in the evening and goes down about 8:30, and your storage battery may connect these peaks by absorbing the surplus and returning it at the time of the heaviest load. It is simply to produce an economy in generation, and thus diminish the losses.

The President: As I understand it, then, the storage battery is virtually a fly wheel.

Mr. Summers: Yes.

The President: That is, it is not an economical thing as far as the transmission of power is concerned, except as to act as a fly wheel.

Mr. Summers: Not at all, and like the fly wheel it is a very heavy piece of machinery to install. In addition, it will depreciate rapidly.

The President: During that period of depreciation the effectiveness of the storage battery is continually decreasing.

Mr. Summers: Slightly, yes. The storage battery is not a direct storer of electrical energy; it stores chemical energy.

Prof. Jackson: I simply want to call attention to a fault in the comparison between storage battery and fly wheel. In the storage battery you have 75 per cent. efficiency and in the fly wheel 100 per cent. It is not a fair comparison.

Mr. Summers: I would deny that a fly wheel had 100 per cent. efficiency. The added weight on bearings, air resistance, etc., preclude that. It is simply a matter of amount; it is not a matter of 95 per cent. or 75 per cent.

The President: The use of the illustration was only intended to bring this subject within the scope of common minds that are not electric experts. I think we all understood that.

Mr. Bley: In regard to the storage battery, it seems to me that if it were granted that the storage battery did not deteriorate very rapidly, then, as far as I have heard anything to the contrary, I cannot see but what it would be a desirable thing to use even in the first installation. Taking the position, as I understand Mr. Barrington does, that you take a storage battery and store up your energy there and use it in connection with your plant to supply the energy when the greatest demand is on, in that way you get along with a smaller plant than you would otherwise. I understand that to be the position taken by Mr. Barrington and if the storage battery will last sixteen years, as it is claimed, I do not see from anything that has been said on the other side that it would not be a fair investment. Of course, if the battery on the other hand is not reliable, that makes a different question.

The continuation of discussion on Mr. Barrington's paper was declared in order.

DISCUSSION RESUMED DECEMBER 9, 1896.

The Chair: I believe at the last meeting there was a statement made bearing upon the economy of the locomotive engine in comparison with other similar machines intended for draw bar pull. Is there any gentleman present who could enlighten us on that point? If I remember right, Mr. Coster made some remark on that subject at the time of the last meeting. Is Mr. Coster present?

Mr. Coster: I simply stated that it was a known fact that by the use of electric locomotives we could furnish a brake horse power per hour with a cost of fuel averaging about two-tenths of a cent. Now we would like to see a steam locomotive that can excel that. We have a good many very able steam locomotive engineers here; we would like to hear their views on the subject.

The Chair: Has the locomotive engine any friends present? Mr. Lundie, could you enlighten us?

Mr. Lundie: Mr. Chairman, I called on Mr. Renshaw of the Illinois Central and asked him if he could give me some data on his suburban locomotives. He very kindly turned over to me what he had in the way of monthly reports of the performance of the different engines. From the reports on six of the more modern engines I found an average of 92 pounds of coal used per train mile. They use Illinois bituminous coal. Now the Illinois Central on the suburban service runs on an average five cars to a train, which would give a train of about 200 tons. They are scheduled to run 20 miles per hour, and the speed between stations runs up to 30 miles per hour. We can do a little figuring on this. In the first place, there

is a certain amount of work to be performed in accelerating the train to a speed of 30 miles per hour; next, there is the usual so-called rolling friction, usually figured at eight pounds per ton; and next there is air resistance. There may be some other minor resistance, but figuring out now, 200 tons accelerated to 30 miles per hour would require about 12,000,000 foot pounds of work. The air resistance—taking it per run of a mile—would require about 8,000,000 foot pounds, and the so-called rolling friction would run about 8,000,000 foot pounds.

The Illinois Central line has stations half a mile apart, consequently in a mile run you have to figure the starting of the train twice. In making a stop the steam is shut off fifteen or twenty rail lengths from a station and part of the kinetic energy in the train is used in running this five or six hundred feet, making the net work of starting about 10,000,000 foot pounds.

This foots up to about 36,000,000 foot pounds of work to be done in running a mile on the suburban service of the Illinois Central. Now the coal per mile, from Mr. Renshaw's statement, runs 92 pounds per train mile; thus, a pound of coal develops at the rim of the wheel something like 390,000 foot pounds. If we divide the different items of resistance by that figure we find 25.5 pounds of coal required for each start; for wheel resistance, 20.5 pounds, and for air resistance the same, 20.5 pounds. Now if you have a central station giving a horse-power hour for three pounds of coal—that is not far out of the way—that would be 650,000 foot pounds for one pound of coal (a horse power hour is 1,980,000 foot pounds). This output would be equivalent out on the road to about 400,000 foot pounds at the rims of the drivers. Thus we have a comparison between the two systems. We have 390,000 foot pounds per pound of coal from the locomotive, and we have 400,000 foot pounds from the central station; or they are practically equal. I would like to hear from some of the electrical gentlemen who will defend the fuel economy of electrical transmission of energy.

Mr. Coster: I wish to take exception to a few remarks by Mr. Lundie, and to differ with Mr. Barrington, who states it is very good practice to produce a horse-power hour at the switch board in the central station for three-tenths of a cent for cost of fuel. There are some instances where we produce a kilo-watt hour, which is equivalent to one and one-third horse-power hour, for .22 of a cent for cost of fuel. Now this item alone will knock the pins from under Mr. Lundie's argument.

As far as economy of the locomotive is concerned, I would like to have it expressed in brake horse-power; that is the way to get at it. In discussing the matter with some very capable locomotive engineers this evening I found that locomotive performance is considered very good if we can produce an indicated horse-power for 26 pounds of water. I do not think they can average that, in fact, I am sure they can not; they may do a little better under exceptionally good conditions, but they can not average that. If we can obtain the average efficiency of a locomotive, we will be able to get at

the cost of a brake horse-power, but the efficiency must be very great indeed to produce a brake horse-power for two-tenths of a cent per hour cost of fuel, with a water consumption of 26 pounds of water per indicated horse-power.

Mr. Chairman, I would like to have you call on Mr. Gibbs, who is mechanical engineer of the Chicago, Milwaukee & St. Paul Railway. Mr. Gibbs is a thorough mechanical engineer and has also paid a great deal of attention to electrical appliances. I understand he has just returned from the East, where he has investigated the problem, and I know of no one here to-night who is better able to give an impartial view on the subject.

The Chair: I am sure we would be pleased to hear from Mr. Gibbs, if he would be kind enough to address us on the subject.

Mr. Gibbs: My ideas on this subject of electric traction applied to steam railroad conditions are in a decidedly chaotic state. I have only lately taken up the question, by direction of our people, who want to keep abreast with the modern developments in electricity, as we are common carriers, both of passenger and freight. I do not mean to say that we have any immediate intention of building electric roads, but we desire to know what conditions we have got to meet in the future, and then we can decide whether it is advisable for us to enter in competition on the same ground. We can not hope to occupy quite the same field which street railways do, for the reason that they enjoy advantages we are not permitted to share. They are allowed to occupy the public streets and especially highways, generally without compensation; they are under very little control, except in large municipalities, whereas we have a costly right-of-way and terminals, and are under all sorts of control, state and city.

I might speak first, while the subject is in my mind, upon the question of locomotive economy. This question can not be answered as definitely as the same one could in referring to electric locomotive, for the reasons that running conditions are very variable, and we have not the constant means of measurement that the electricians have. They have only to measure their power by taking the volts and amperes, in fact, they have integrating power-meters for doing this. We have no such instruments which can be applied to locomotives, and if we had, we still have the complicated questions of variable boiler economy to deal with. However, I have personally, and other railroad engineers have made tests of the fuel and water economy of locomotives, and we think we have got, within certain reasonable limits, the approximate figures for certain given conditions.

I have found that under average conditions of express freight service we can obtain an indicated horse-power hour with 26 pounds of water, that is, averaging an entire trip, including both stopping and starting several times, and with different conditions of grade over the line where the locomotive would be worked with variable cut-off. It will be seen that this figure is surprisingly good.

Now as to the fuel economy. This depends upon the rate of combustion and quality of fuel; but under the conditions above men-

tioned, express freight service, with Illinois coal it is quite possible to obtain an average evaporation of between five and five and one-half pounds of water per pound of coal from the temperature of feed water, say 60 degrees Fahrenheit. If we assume these figures, this would give us a horse-power hour for 5.1 pounds of coal, and assuming the same figure for cost per ton of coal, which Mr. Coster has mentioned, would make the cost of indicator horse-power hour .26 of a cent, instead of .2 of a cent. A compound locomotive, however, gives an opportunity for reducing this figure; we are obtaining an average efficiency of nearly 20 per cent. better than this, and the water consumption as measured by another road very carefully runs as low as 23 pounds per indicated horse-power hour. I think this can be nearly duplicated in everyday practice.

I read Mr. Barrington's paper with a great deal of interest and agree with him as to the general conclusions. He makes a remark: "The revolution, or evolution, will assuredly come, but more in the form of an extension of improved street car service, rather than a wholesale substitution of electric motors for steam engines."

That I think states the case extremely well. I think there is an exceedingly large field for electric traction in suburban service. We have possibly here an example of it, say the Illinois Central road. They have heavily loaded trains running at frequent intervals on a right-of-way which is quite free from grade crossings where they can maintain their current conductors without interference or danger to the public, and it seems to me if there is any place where electric traction can be run economically, this is the one.

Of course in figuring such a scheme out there are several questions to be taken into account. The first is, whether electric traction is an electrical success. The second is, whether it is a railroad proposition, that is, whether it will fill railroad conditions. The third is, will it pay?

I think there is very little reason for examining into the question of successful propulsion of trains by electricity. It appears to be entirely feasible for trains of any weight and for any desirable speed.

The second question, as to its adaptability to railroad conditions, is rather more difficult to answer. It seems to me from what I have seen that the question of getting the power to the train from the feeding wires is one of the most difficult electricians will have to handle, and I have seen no effective or mechanically acceptable solution yet offered for heavy service. The trolley is adapted to light, slow speed car service, but not heavy service. The third rail seems not adapted to all railroad conditions on account of switching movements, highway crossings, and danger to the public and employes.

As to the question of operating cost, I am not well enough informed to say much about it. The fuel economy at the generating station is only one of the elements. I am willing to accept Mr. Coster's figures for the cost of generation of power under the best conditions. I think, perhaps, he is a little optimistic in assuming that those conditions will always be maintained in a service that is not uniform in amount. As to the operating and the repair cost of

motors and other electric equipment, we really know very little about it. From what I can see, it will be very little less than that for steam equipment, but I do not see why it should be very much greater. Each particular case will have to be taken up by itself, and it would be folly for me to express any conclusion I have not arrived at.

The Chair: How does the application of electric power to railway service relate to the question of speed? Could you answer that, Mr. Gibbs? I think that a year or two ago there was a scheme projected for a rapid railway service between Chicago and St. Louis, of 100 miles an hour.

Mr. Gibbs: The question of speed is, I think, not materially affected by the substitution of electric traction for steam. Locomotive speeds to day have been obtained and can be obtained, if we are willing to pay for them, as high as it is safe and desirable for economic reasons to adopt. Locomotives with a very light train can be run about 90 miles an hour, perhaps more. It takes the most perfect track, as no doubt many of your members will testify, to make riding at such speed as that comfortable, and economically it is an absurdity, both from the track and machinery maintenance and from the fuel consumption points of view. I do not anticipate any great increase in maximum speed. The question of average speed is an entirely different one, and that is one in which we have great room for improvement in steam railroads, and we have got to meet the same problem in electric roads.

The Chair: There is an application of electric power to what might be termed an extensive tramway system in Cook or Du Page County, immediately west of Chicago. I think the railroad is some 20 to 40 miles long, extending from the vicinity of Elgin southward, taking in Aurora. The road is built with the T rail standard gauge, and they haul the ordinary freight cars over the road; I think their passenger service is in isolated cars. Could any one make any remarks as to the merits of the electric application in a case of that kind, where the county seat is reached from a number of small towns in the whole county, or where a light freight traffic is carried on? Does any one know of the case I am mentioning? the name of the road I have forgotten.

A Member: It has not been operating long enough yet for any one to get any data upon it. It has only recently been completed, less than a year.

The Chair: Would Mr. Arnold favor us with some remarks on this subject?

Mr. Arnold: The question which, it seems to me, the steam railroads must meet, is not a question of whether they can operate cheaper than electric roads can, but whether they can hold their present traffic in competition with electric roads which have already paralleled them in many instances, and will continue to do so, although they may not parallel them for great distances for some time to come. They will parallel them, however, for suburban service, and between county seats, as in the case mentioned by the

chairman, where there are a number of cities of from three to five or six thousand people, varying from six to twenty miles apart. This affects a certain portion of the steam railroad traffic, or draws from it, but for through traffic lines I am not of the opinion that the electric motor for heavy traffic can at present compete with the steam locomotive for economy, if it is judged entirely from the standpoint of fuel consumption where the interest on the investment is considered. The figures given here to-night we have seen check out very closely. The electric advocate gives the cost per horse-power hour as .2 of a cent at the power station; the locomotive man gives it as .26 of a cent at the locomotive, with a simple engine, while with a compound engine he gives it 20 per cent. better; that brings it pretty nearly to .2 of a cent per horse-power hour delivered at the locomotive. This being the case, you cannot expect to produce a horse-power hour in a power station at .2 of a cent and deliver it to an electric locomotive some miles away for .26 of a cent, and effect a saving, for the reason that the difference of .06 of a cent per horse-power hour must pay the interest on the extra cost of the electrical equipment of a road over its present cost as operated by steam, which I do not think it can do on roads operating few and heavy trains at long intervals in accordance with the present standard system of railroading. This is the comparison that it gives with a heavy freight or passenger service, but when you come to the condition of handling small trains at short intervals, I think that the electric trains will supersede the steam trains in almost every instance, and the prominent case that we have in mind is the Illinois Central right here near us. I understand by reading over the discussion which took place here a week ago, that the officials of the road are willing, or rather have expressed an indication that they might adopt electrricity if they could be convinced of the economy of it. If I read the figures correctly, which were handed me a couple of hours ago, of the operating expenses of the Illinois Central Road, and the estimated cost of operating it by electricity made by their own engineers, I figure out a saving of something like $250 per day, from their own figures. If that is the case, the question, it seems to me, is decided in favor of electricity. These figures include interest against the cost of both locomotive equipment and the electrical equipment, and therefore take in the whole question. Possibly these figures may be corrected after proofreading. They were handed me in their present condition. Be this as it may I desire to call attention to the fact that while these figures have been very carefully made, and with evident fairness and impartiality on the part of Mr. Parkhurst, they nevertheless were made at a time when the cost of electrical machinery was much higher than it is at present, and the engineering question affecting the cost of the production of electrical energy in the power station were less understood than at present, and that if the figures were modified to fit the conditions as they exist to-day, the conclusions deduced would be much more favorable to electricity.

In reading the discussion which took place here a week ago I noticed that one speaker (and it was the gentleman who has advocated electric traction the strongest this evening) used these words: "There is no doubt that electricity has failed on the elevated roads in Chicago, for if it had not the very able financiers connected with those roads would not have decided on a change." I think that must be a typographical error, because I know of no indication or disposition on the part of any one to go back to steam on the elevated roads.

Mr. Coster: I did not say it was a failure; I said it was a success.

Mr. Arnold: I wanted to bring that out, because your last statement is certainly correct. In conversation with an official of one of the recently electrically equipped roads, it was stated to me that the saving in labor alone had been several thousand dollars per month over what it was with the steam equipment. The whole question has not yet been determined, because they are operating under abnormal conditions; yet there is a marked saving, especially in labor, making a great total saving. I know from a comparison of the operating expenses of the Intramural Road at the World's Fair, the Liverpool Overhead Road and other electrically equipped roads with the Manhattan in New York and the Alley Elevated here, that electricity shows a decided saving over the steam operated roads.

Now to get back to the question of what we are going to do to get electricity to our heavy and sparsely distributed trains, if we are ever going to get it so delivered, I confess I see no way at present of getting the current from the power station to the trains by means of overhead or underground conductors without an uneconomical loss, that is, a loss within reasonable limits which will allow electric locomotives to compete with steam locomotives on heavy train service with trains far apart, when considered from the standpoint of fuel economy alone. I do see a very clear and distinct way by means of either the overhead trolley or third rail system of getting the power there for suburban work and for light trains that are run under short headways. There is no question that this problem can be solved on the Illinois Central by any engineer skilled in this particular class of work, if an opportunity is given him, but he would not want to undertake the other problem and attempt to solve it satisfactorily to the officers of the road at present, unless something besides fuel economy was to be considered.

Mr. Lundie: The figures that I read a few minutes ago will run about .25 of a cent to the brake horse-power hour. I may say (I do not know whether I am authorized to say it or not; if I am not I will eliminate it from the printed discussion) I got some information from the officers regarding their operation, and the cost of train mile runs from 9 to 15 cents, and the cost of fuel is somewhat in excess of 4 cents per mile.

Mr. Arnold: I have the operating expense for the year 1892 here in this book, and I believe that I am not violating any confidence, inasmuch as the Illinois Central officials have given quite

completely these operating expenses in another part of this discussion, when I state for information that the total average cost per train mile of the suburban service for the year 1892 was 14.68 cents; I do not offer this as a correction of Mr. Lundie's figures, but to show that the actual average expense is very near to his upper limit figure.

Mr. Coster: The gentleman here stated that the cost of fuel given by him would figure to .25 of a cent per horse-power hour. He is figuring that to the switch board?

Mr. Lundie: No, sir; I am figuring it out on the track.

Mr. Coster: Will you tell me how much you allowed per horse power?

Mr. Lundie: I am figuring on the locomotive.

Mr. Coster: I thought you said the cost of fuel, according to your figures, per electric horse power was 25 cents.

Mr. Lundie: No, per brake horse power hour of the locomotive.

Mr. Coster: We can do it for .22 under the worst conditions, and you are doing it for .25 of a cent under the best conditions.

The Chairman: Is Mr. Cutter present?

Mr. Cutter: I have not made a study of the subject at all. I am free to admit that I think we will produce our electricity direct from the coal about as quickly as we will convey it to the trains on steam railroads. I believe that the work is already well in hand—producing our electricity direct from the coal and doing away with the steam engine altogether. Why, the Jacques method of doing that already gives 32 per cent of the theoretical power in the coal—of course, with only a small apparatus, a two-horse power. He is now making one of 40 horse power, and expects to get still more efficiency, but that is about twelve times the efficiency we get from electricity going through the steam engine and the boiler.

The Chairman: A body blow for the locomotive.

Mr. Arnold: I certainly do not agree with the last speaker as to the immediate prospects of success for application of the improvement he mentions, as I have investigated the subject quite thoroughly lately regarding the production of electricity direct from coal. I do not mean that I am capable of going to the bottom of it from a scientific standpoint, but I have looked up information as best I could, and I can see no real foundation for expecting immediate extensive results from Dr. Jacques' accomplishments, judging from the published descriptions, although I do not wish to take the position that his experiments have no value, for they seem to indicate a marked step in advance, and may lead to results more encouraging than those given at present. In considering his results, it should be borne in mind that they were obtained from a primary cell, consisting of a carbon electrode immersed in a caustic soda electrolyte. Through the electrolyte was forced a current of air under pressure, the function of the air evidently being to supply oxygen for some purpose deemed necessary by the experimenter. The electrolyte, at the same time, was heated by means of the combustion of fuel placed immediately under the vessel containing the electrolyte and main-

taining the electrolyte at a temperature of about 500 deg. Centigrade. The data published regarding it shows an efficiency of 82 per cent of the theoretical energy obtainable from the carbon consumed in the cell itself, and after taking into account the allowance made for the coal consumed in the furnace to maintain the electrolyte at this high temperature, and the energy necessary to force the air through the cell, the net efficiency is stated to be 32 per cent of the total energy of all the carbon consumed. While this result is remarkable, and I believe we all hope it will prove true in practice, yet we should bear in mind that the advantages set forth in the first published accounts of any improvement of note are usually overestimated, and for the further reason that Dr. Jacques himself, in a recently published magazine article, states that it will be some time yet before the dynamo and steam engine will be relegated to oblivion, I feel we should not be too sanguine regarding his discovery.

Chairman: Suppose a large water power were available for generating electricity, within a distance of say 40 or 50 miles from the point of application, what figure would that cut in the availability of electricity for a motive power?

Mr. Arnold: Under fair conditions you would save about one-half of the cost of the fuel; the rest would be absorbed by the increased investment over ordinary steam plant. That is, you would save about one and one-half pounds of coal per horse power hour, but when you have water power you are usually forced to put in a great investment in the way of dam, wheels, etc., and for the transmission line, consequently you cannot figure that you get all your power free of charge. You have got to pay interest on your investment, and where water power is not favorably located it is often cheaper to put down a steam plant near the work and buy coal than to use the water power.

The Chair: I asked the question, of course, on the hypothesis that the water power was readily adapted for the location of the wheels.

Mr. Arnold: It is certainly desirable to utilize all the water power that we can. One further statement should be made about that. That is, that there is a prospect in that direction of being able to utilize water powers much more than we do at present, when we can handle electricity at a higher voltage than we now do. While we are now limited to a pressure of 5,000 to 10,000 volts, we should have great expectations in that direction, because if we can in the future handle current by the means of improved insulating devices at double this pressure, we can transmit it long distances at a great deal less expense than we can now, and, therefore, utilize these water powers that are at present idle. It is in such application that the multiphase or alternating systems have proven their superiority, and it seems probable that they will continue to hold their supremacy.

The Chair: There are so many large and available water powers scattered over the country that can be used, for instance, at Washington City and Sault Ste. Marie and other localities of that kind.

Something was said at our last meeting with regard to the utility of storage batteries in connection with electric traction, either to

pass out or in original installations, or something of that kind. Has any one remarks to make on that subject in this meeting? Prof. Jackson, have you anything new on that subject this evening? Mr. Arnold?

Mr. Arnold: I have already done my duty, I think. I had not expected to say anything about the storage battery question, because whatever I might say would perhaps be considered somewhat biased, and I do not want to be thought too much that way. However, I have had some experience with storage batteries, and so far as their application as auxiliaries to direct current power stations is concerned I am perfectly satisfied with the results that have been obtained, and am convinced that batteries as auxiliaries have a very broad field, and that there are many power stations that can adopt batteries and effect a saving in operating expenses, and in addition to this have a reserve supply of energy on hand to draw from in case of accident to any of the machinery part of the plant. In this way I think batteries will come into use very extensively, and in that connection I might state that I recently made a trip through the East to see what has been done in this direction. We in the West are skeptical; we, or at any rate some of us, think we are doing a large amount of the experimenting. I spent a great many dollars experimenting on this subject, and thought I had done something. I went East and found "the other fellow" had done a great deal more, had thought it out more completely, and had spent more money and on a great deal larger scale. So I say, not being surrounded with battery plants in this territory, we are likely to think that they are not as practical as they are found to be on thorough investigation. To emphasize this I want to call attention briefly to the plants which I saw and the approximate investment in batteries that is now being made.

At the Philadelphia Edison Station I saw $80,000 worth of batteries going into one plant. I give the sizes of the plants in dollars to give you an immediate tangible idea of how desirable the companies must consider these batteries. At the Twenty-third street station of the New York Edison Illuminating Company they have one battery that cost probably $40,000. I understand it has been in operation about two years; the same company has recently put in a second battery in what is called their Bowling Green plant, down town on Bowling Green Square, but instead of putting in engines, boilers and generators, as in a regular sub-station, they have eliminated these entirely and put in a large battery auxiliary, and they are going to use the battery as a distributing station and charge it from their main power plant. They have, I believe, put about $80,000 into this battery auxiliary. Then the Brooklyn Edison Company have a new battery, costing about $50,000, in one of their substations.

Up at Hartford, Conn., there is a water power located some seven miles away from Hartford, which is to be utilized in the manner suggested by the President. They are putting in a dam and power plant, and are going to transmit the current by means of high volt-

age lines and alternating circuits to Hartford and there, by means of rotary transformers, convert it and put it into these batteries. They have invested something like $150,000 in batteries, by which means they will annihilate their central station in the city by taking out completely their engines, boilers and generators, and are going to distribute their current direct from the battery plant.

In Boston the Boston Edison Illuminating Company have had two batteries, their combined cost being approximately $200,000, in use for about two years that have given good service. They think enough of them so that they are now installing the third as a sub-station, costing probably $75,000, putting in no engines and boilers, but in their stead this battery auxiliary. There is another plant at Easton, Pa., in connection with railroad work, costing probably $20,000. The costs of these plants, as I have given them here, are only approximate, and based only on my ideas of their cost, after knowing something of their size, but without any definite knowledge of the actual cost in any case, but if any error has been made I believe it is in underestimating their cost, in order to be on the safe side and so that my remarks may not seem to exaggerate. These plants opened my eyes somewhat; although I was a battery man to a certain extent, I had no idea that other people had so much confidence in batteries, but they seem to have shown their faith a great deal better.

I have one plant here in the Board of Trade which I installed there as consulting engineer for the Board of Trade, and which I believe is giving as excellent service as could be asked for, and which any of you are at liberty to examine at any time. It has been in use for eight months, and it has not cost anything for maintenance; it will no doubt from this time forward cost a little something, probably about four to six per cent per annum is what I anticipate, but it is not enough but what in my judgment the plant will prove a good investment. It is certainly saving quite an amount of coal and gas. I do not want to state the figures at present, but at the end of the year I propose to publish the operating expenses of the plant for the year prior to the adoption of the battery and for the year following; then it will be judged for itself.

Mr. Jackson: I wish to add a few words to my remarks in regard to storage batteries. As my remarks in the first discussion of Mr. Barrington's paper show, I regard storage batteries as useful appliances when in their place; but as at present constructed, at least, their place is limited. A storage battery is essentially a money waster, inasmuch as it does not return, when discharging, all of the power which was used in charging it, and the expense required for its maintenance is considerable. In a plant with a variable load, or where during a portion of each day the demand for current equals only a small part of the maximum demand, and under some other conditions, the addition of a storage battery sometimes will result in a net saving through the power of the battery in (1) steadying the load, (2) assisting the generating plant at moments of excessive load, or (3) of assuring against stoppage of current through the

temporary breaking down of the generating machinery. A battery may in some cases save sufficient money through these powers to make itself a profit gaining place in a plant. In every case of economical results due to a battery, the economy must be brought about indirectly by the battery through (1) increased economy of the prime generating plant due to a steadier load, (2) reduced first cost of generating plant on account of the assistance of the battery at times of excessive load, (3) convenience, or (4) assurance against failures. The total saving in any plant which is brought about through the use of a storage battery must have written against it the expenses and losses directly due to the battery itself, and unless the savings are very considerable a satisfactory net balance will not be shown. As far as I have been able to learn or understand, the storage battery in its present form has only proved itself to be conducive to economy when used in the very large electric light central stations. In these it appears to add an economical factor to the station (notwithstanding its direct expense and losses) through distributing the daily load more uniformly through the twenty-four hours. It does not appear that the storage battery has yet shown that it has any large part in electric traction, though many attempts to demonstrate its importance have been made.

Mr. Lundie: I would like to ask Mr. Arnold what is the life of a battery?

Mr. Arnold: No man can tell you that.

Mr. Lundie: It was stated here at the last meeting, I believe, by somebody.

Mr. Arnold: I can tell you it depends on how it is used. It is like a steam locomotive, dynamo or anything else which should have some attention, although a locomotive is somewhat different; it is run by different men, and the men are always of about the same skill; it gets a certain kind of expert supervision all the time, and is run under practically the same conditions, so far as expert superintendence is concerned. The battery is another thing, because it is a silent, willing and solitary worker; it will work uncomplainingly till there is nothing left in it, nobody knowing about the damage until it is done, unless it is taken care of by an attendant who will not overwork it and who can detect any slight defect at the right time. A battery operated under unskilled hands may go to pieces in a few years, although there are cases where plants so operated have done good service for years, but a battery operated under skillful management and not overworked ought to last, I think, from fifteen to twenty years. Probably the positive plates would have to be renewed a few times, and some attention given to the negative plates at a probable expense of not to exceed five to six per cent per annum during the total number of years. There are a great many plants that have been run for eight or ten years and are still doing good service.

A Member: I would like to ask Mr. Arnold if he has not had some experience in applying batteries to street car service?

Mr. Arnold: I can answer that question very quickly. I have not. I hope to have, though, inside of a year. In the course of a year I hope to be able to give you some data that will be either very encouraging or very discouraging. I cannot now tell you which, but from reports I have from battery cars operating in Europe and from the method pursued by the builders of the Englewood & Chicago road in this city, which is now equipped with batteries, I hope for satisfactory results.

Mr. Herr: I agree entirely with Mr. Arnold on the feasibility of electric traction superseding steam locomotive in suburban and very light and relatively frequent passenger service, but there is an obstacle, it seems to me, or at least an impediment, to its superseding the steam locomotive in heavy through service, especially in freight service. That has not been mentioned, and that is the practical matter that at least all Western roads are obliged to meet of the very heavy fluctuations in business. On the Northwestern road, with which I am connected, we have many divisions, in fact, on some of our principal divisions, in which it is not unusual for the freight to fluctuate 100 per cent. Conditions of that kind, it seems to me, will militate very seriously against the application of electric power. With the installation of electric motors on any division of a railroad you would be obliged to install for maximum power; you would be obliged to install your central stations with feeders, wires, everything that pertains to the permanent structure, for the maximum of power you would be obliged to have to handle additional cars, and this maximum power would only be used perhaps 8 per cent of the year, and the balance of the time your structure would be carrying a very great underload. With locomotives it is very readily handled; that is, while we may be doing a very heavy business on one division, we transfer our locomotives from one division to another, and they are run very economically, or if the business is light throughout the road, the locomotives are tied up. Of course, by dividing the power units the whole division could be made, but I fail to see how it could be done in wiring and other structures that must necessarily be made for the maximum power.

The Chair: That brings out another phase of the subject. Are there any remarks upon that, or upon any other matter relating to the question of electric traction?

There is one matter in connection with electric traction which was the subject of a paper before this society about two years ago by Prof. Jackson, who is with us this evening, on the question of electrolysis. I believe we would all be pleased to hear if Prof. Jackson has any new matter this evening from that which he so kindly advanced on the former occasion.

Prof. Jackson: As regards electrolysis (the corrosion of iron pipes and other underground metal work by reason of the ground return of street car circuits—stray currents due to street car circuits), I think I am safe to say that what appeared to be a very grave danger has been brought within entirely reasonable limits. In some cities where appearances at one time indicated that there might come

a time when underground metal work could not be kept intact more than a few weeks, on account of the electrolytic corrosion, the condition has now become so that the corrosion of underground metal work is not much more than that which would be expected from the ordinary action of the earth. This has been brought about, of course, by thoroughgoing, substantial electrical construction. Those who were interested in the early days of electric railroading went through a period of exceedingly bad construction, and it has been by experience that the electric railways have learned that it is to their own benefit (conducive to their own economy) to construct their circuits in thoroughly first-class manner. This includes the construction of the ground circuit in such a way that there is not an undue loss of power in the ground return. With the first-class construction which we now find carried out in the more important cities I do not think there is much danger from electrolysis, and I think the insurance men who have looked over the thing lately have come to the conclusion that we are not damaging the water pipes or increasing their risks in cities where proper precautions, as set forth in my paper of two years ago, have been taken. In the case of a suburban road, such as the suburban lines of the Illinois Central, if a maximum total loss of ten per cent were allowed (which would mean about five per cent each in the overhead and ground circuits) I do not believe there would be any real danger if reasonable care was taken with respect to a few possible points of danger that might show themselves when operations started. I am perfectly safe in saying that the last two years have not only tided us over what then seemed a grave difficulty, but they have put us in a position where we are no longer in danger, provided reasonable precautions are taken.

The Chair: I am sure it is looked upon with very much less apprehension today than at the time I was speaking of. If I remember, the questions of the foundations of our buildings were supposed to be doubtful at that time.

There is one other feature in the matter of electric traction that is kindred to the features that we have been considering this evening, and that is this question of roadbed construction, with regard, first, to the continuous rail, and next with regard to what is perhaps more interesting, to rigidity of roadbeds. At a meeting of our society about a month ago the question was touched upon by Prof. Hunt, Mr. Bley and some others, and they seemed to think that there was something in the idea that perhaps our forefathers were right when they undertook to build a railroad on solid rock. Has any one present any ideas on that subject, or considered the matter with regard to continuous rails, or with regard to rigidity of roadbed? Mr. Gibbs, have you considered that part of the subject much?

Mr. Gibbs: Mr. Chairman, only from the standpoint of an observer. I do not believe continuous rails can be made a success on ordinary railways, but in street railway tracks they appear to work well—probably because they are buried below the surface and held by the pavement so that expansion strains are relieved progressively instead of being allowed to accumulate at isolated points.

I have been much struck, in the past, with the exceedingly bad roadbed construction on street railways. The work of construction in city streets is necessarily expensive, and should be done in the most permanent manner; yet these railways have put in the flimsiest sort of track, held with complicated fastenings, and carried on soft wood ties of poor quality. We have all seen and felt the results, and, as steam railway engineers, have watched with some amusement the progress of the schooling of the street railway management.

I wish to take this opportunity to say that in the criticisms I have made regarding electricity as applied to steam railroad conditions—I do not want to be understood as wishing to say anything to discourage electricians from working at the problem—it is new in many features to a great many electrical engineers who have worked at it; they are not railroading men, and can not be expected to know exactly all conditions they have got to meet, and I think a full discussion in this way, bringing out the difficulties, will be of assistance in helping them to solve the problem, and as steam engineers, we are ready to help them out. Perhaps the combination will evolve something which is adapted to fill a certain field in our service; I sincerely hope it will, and believe there is a very large special field for it.

Mr. Arnold: Mr. Knox, of the Chicago City Railway Company, is here, and he ought to have some knowledge on welded rails.

Mr. Knox: It is very true, just as Mr. Gibbs has told you, that the greatest difficulty in street car traffic is to get the management to see that it is a great detriment to construct tracks as they have been wont to do with the old horse car service, because the motor is so heavy they pounded the joints out of sight, but to solve the problem the road with which I am connected, the City Railway, have adopted the cast weld joint, and I believe it to be a real success. I do not believe it will be a success where the rail is not buried, thereby keeping it at an even temperature, but I may state that we have in use now between thirty and forty thousand joints; during this extreme cold weather we were only able to find about ten joints that had broken during that cold weather. The first year we put the joints in use, out of perhaps 12,000 we lost 160 odd. Those that broke were broken on account of the joints being imperfect. As far as handling the rail problem is concerned, I believe with this joint that we will have no more difficulty in having a good roadbed for surface roads.

The Chair: Would there be any objection, under conditions of continuous joints, to have a very rigid roadbed?

Mr. Knox: No, sir; I do not believe there would be very much difficulty in that direction, provided, as I say, you kept your rail well covered, with an even temperature.

The Chair: Is there any rule in your practice with regard to the length of track jointed together without openings? Any allowance for expansion?

Mr. Knox: No, it made no allowance whatever in that line. We have rather gone on the theory that the rail will stretch about so

much and compress about so much, which we find to be true. We have a little difficulty, I will say, in the casting of this joint at first, of the rails buckling up, as it were, but that has been entirely eliminated by putting on clamps with the casting, forcing that joint down, and then forming the casting, and in that way we get a very straight rail.

Mr. Nichols: So far the discussion of the subject has followed the line of heavy traction on main lines and also for street car service; but there seems to be a great field for electric traction in mine locomotives, for hauling the cars in and out of the mines, in which the locomotive develops considerable power, about 200 horse. Also in and about Chicago there are a number of small locomotives for handling loads about the yards; for instance, Armour has a large plant for hauling his pork from one house to another, an elevated structure, and while it does not cut any great figure in electric traction, it is very useful and very valuable.

The Chair: That is an important part of the subject. There is no question about that miscellaneous adaptation of electric traction to economic purposes.

XXI.

THE EQUIPMENT OF MANUFACTURING ESTABLISHMENTS WITH ELECTRIC MOTORS AND ELECTRIC POWER DISTRIBUTION.

By Prof. Dugald C. Jackson, Mem. W. S. E.

Read December 9, 1896.

The theoretical treatment which this subject has heretofore received in papers before technical societies or articles in current periodicals has always appeared to me to be inadequate, and I have therefore undertaken to give a summary of the views held in a number of the great manufacturing establishments where experience has been had with electrical transmission and distribution of power. In a considerable proportion of these establishments electric power transmission has been used side by side with the mechanical transmission of power from the prime mover to the operating machinery. I propose to deal specially with the conditions which exist in establishments owning and operating their own complete and independent power plant.

The points to be considered in a comparison between mechanical and electrical distribution of power in manufacturing establishments by which the advantages of one or the other are to be determined are:

A. Comparative first cost.

B. Comparative operating advantages.

1. Annual expense for fuel.
2. Annual expense for attendance.
3. Annual expense for repairs.
4. Frequency and duration of breakdowns, and extent of the whole plant which is likely to be affected by a failure of any part.
5. Convenience, as it affects the extent of floor space occupied by machinery.
6. Convenience, as it affects the handling of product at the machines and to or from the machines, and the amount of product put through the machines.
7. Safety.
8. Cleanliness.

I will take these points up in their order.

A.—COMPARATIVE FIRST COST OF ELECTRICAL AND OF MECHANICAL TRANSMISSION.

In the Case of a New Establishment.—The first cost of electrical transmission within the confines of a manufacturing establishment which has its own independent and complete power plant is nearly

always considerably greater than the first cost of mechanical transmission, such as by gears and shafting, belts and shafting, or ropes and shafting. In each case the steam plant is required. In the electrical equipment the required parts in addition to steam plant are electrical generators, electrical wiring, electric motors. These are considerably more costly under ordinary conditions than belts and shafts or other mechanical transmitters, even if we acknowledge an advantage in the efficiency of the electrical plant which permits a reduction of the total capacity of the steam plant when electrical transmission is used.

The electrical equipment being, under ordinary conditions, more costly it must make sufficient annual savings to pay a profit on its extra first cost or it has no reason for its existence.

In the Case of an Established Concern.—The considerations of the last paragraph apply with extreme force in a case of a proposed change from mechanical to electrical transmission in an established concern, as such a change means, at the best, the abandonment of much operating transmission machinery. In some cases special considerations may enter, as is shown later.

The possible savings are discussed below under the respective headings belonging to the following divisions of

B.—COMPARATIVE OPERATING ADVANTAGES.

1 and 2. *Annual Expense for Fuel and Attendance.*—The following quotation from an editorial item which appeared in one of the technical journals nearly two years ago puts the argument upon these points which favors electrical power:

"It is perfectly clear that Messrs. ——— have derived to the fullest extent the great advantages offered by electric transmission; they have saved valuable spaces formerly occupied by steam engines, and they have abolished to a great extent the losses due to mechanical transmission. The concentration of the whole of the steam plant in one compact space has led to great saving in labor, the majority of the men who formerly attended to the scattered steam plant being drafted into other work. It should also be pointed out that large compound and condensing engines are used with consequent economy. The central station which supplies the power has a capacity of 1,500 horsepower. * * *"

"At the ——— mills there will doubtless be a gradual but complete abandonment of isolated steam plants, for the proprietors are completely alive to the manifold advantages of concentrating steam raisers. It is yet too early to expect detailed costs of working, but there appears to be the greatest satisfaction with the general performance of the electric machinery, and a settled conviction that it is the only system which can efficiently supply power to scattered buildings."

This argument seems to be well supported by experience in great manufacturing establishments where hundreds or even thousands of horse power must be distributed over a considerable area. In

the establishments of less magnitude, such, for instance, as use not exceeding 250 horse power, it is questionable whether any very large fuel saving can be shown by the electrical plant under ordinary conditions, and certainly no appreciable labor saving can be shown in the power plant. These deductions are supported by the following quotations from records of the experience of a considerable number of manufacturing establishments, the names of which are in most cases synonymous with success:

Establishment A. Capacity of electrical power plant is 1,537 horse power. Product heavy and bulky. "We have kept no record, but note no appreciable difference." (Referring to comparative fuel cost.)

Establishment B. Capacity of electrical power plant is 1,099 horse power. Product heavy and bulky. "Can give no definite information, but confidently expect the electrical transmission system will show the best results." This plant has just been installed and has scarcely started running.

Establishment C. Capacity of electrical power plant is 633 horse power. Product easily handled. "We think it is economical to use electricity as a motive power when it is desired to concentrate power centrally and distribute the same to different parts of the plant covering a large territory. That is, we think power can be distributed more economically by the use of electricity than by belting to long distances or by other means of transmission; and we also think it is a great deal more economical to concentrate our power than to attempt to distribute it in different parts of our plant by the installation of separate steam plants, or perhaps by distribution of engines, steam for which would have to be carried considerable distances. Can give you no comparative figures."

Establishment D. Capacity of electrical power plant, 600 or 700 horse power. Heavy product. We "are not yet in a position to give you any information that would be of value at all, although our electrical experience would indicate that we had made a change in the right direction." This electric plant was lately started.

Establishment E. Capacity of electrical power plant 400 horse power. Product easily handled. "No figures, but considerable economy" in electrical plant.

Establishment F. Capacity of electrical power plant 275 horse power. Product bulky. "We have made no comparative tests to determine whether or not we were saving any money by this system of distribution, it being largely with us a matter of convenience as at present operated."

Establishment G. Capacity of electrical power plant, not including cranes, 211 horse power. Product heavy and bulky. "We find it much more economical to run by electricity than we did by steam."

Establishment H. Capacity of electrical power plant, 200 horse power. Product easily handled, but cleanliness of importance. "In part of our works we transmitted power by means of belts and gears before we installed electric motors. We have

recently added to our plant a new building, to be equipped with about 400 horse power, in which we intend to drive all of our machinery by electricity, owing to the fact that, according to our calculations, much power could be saved in transmission and our machines could be made more efficient and more easy to control and there would be less working loss in our business owing to the decrease in the liability of damage to our working stock from the effects of the dirt thrown from shafting, belts, pulleys, etc."

Establishment I. Capacity of electrical power plant, 193 horse power. Product heavy and bulky. "We have no data on this subject for comparison."

Establishment K. Capacity of electrical power plant, 185 horse power. Product bulky. "The comparative saving in the changes we have made in substituting electrical machinery for shafting and belt transmission is about 33 1-3 per cent in fuel."

Establishment L. Capacity of electrical power plant, 150 horse power. Product easily handled, but cleanliness of importance. "Our plant is not entirely electrical, being rather a combination with transmission by belting and shafting. We have, however, thoroughly convinced ourselves of the economy of an electrical plant, and were it not for the very large investment involved to make a complete change, should not hesitate to do so, and, were we constructing an entirely new plant, should certainly make it electrical throughout."

Establishment M. Capacity of electrical power plant, 100 horse power. "Have not been able to make complete tests." And further, "We contemplate in future changing more entirely to electrical power. At present a little over half is covered in this way."

Establishment N. Product easily handled, but cleanliness of importance. "Our works are so constructed, and so run, with a mixture of various industries, which makes it impossible for us to know anything about these matters more than this—we find the use of generators and motors for certain parts of our power transmission so much handier, neater, cleaner and more desirable that even if it were not economical from the standpoint of fuel economy we would certainly desire it in preference to line shafting and belting."

Establishment O. Capacity of electrical power plant, 55.5 horse power. Product easily handled. "We do not think there is any question but that it is more expensive in the matter of fuel to run the works by electricity than it would be by direct power from the engine."

3 and 4. *Annual Expense for Repairs, and Frequency and Extent of Failures.*—I have now given you the experience in regard to the comparative cost of fuel and attendance of fourteen establishments covering a wide range of industries from iron mills and locomotive works to spinning mills and manufacturing pharmacists. The experience of the same establishments upon the relative expense for repairs upon electrical and mechanical transmission, and

the relative extent and duration of breakdowns occurring with the two systems of transmission is equally remarkable.

A. "The repairs to motors is much less than that formerly made to belts and line shafting. We have had no trouble whatever from breakdowns worth mentioning in either system."

B. The quotation already given covers these points.

C. No comparative information.

D. Covered in general under quotation previously given.

E. Apparently no great difference.

F. Covered in general under quotation previously given.

G. Repairs "75 per cent less since using electricity." "We have never had but one breakdown since running our electrical plant. * * * The armature of one of our small motors got full of water and burned out. This is the only accident or breakdown we have had."

H. "The comparative cost of repairs is much less in electrical transmission than in mechanical." "We have suffered no loss of time from this cause (breakdowns) during five years' experience with electric motors, with the exception of two instances, where armatures were burned out. We now keep duplicate armatures and there is no loss of time, as a new one immediately replaces the one damaged."

I. No comparative information.

K. "The cost of repairs is in favor of electric transmission, it being about 25 per cent cheaper. Comparing breakdowns of the old system with those of the electrical, a breakdown in the old method (mechanical transmission) always means the shutting down of a whole building or at least a whole compartment in that building, while with the electrical method it means only one machine, or at furthest only a group of machines."

L. "In our case we should not say that the cost of repairs is any less for an electrical plant than otherwise, for the reason that we have such an extensive installation as to require the services of an electrician, whose salary is probably something more than we would have to pay for repairs on some other basis." (Electrician also cares for lighting plant.) "Through having made our installation from specifications and contracts drawn up by an extremely competent electrical engineer and also being fortunate in having very competent men in charge of our entire steam plant, we have never had a breakdown in either system."

M. "Cost of repairs has been smaller than we anticipated. Have had but little trouble from breakdowns."

N. No comparative information.

O. "We are under the impression that there is more expense in keeping these motors in repair than there would be with direct power."

Summing up the general opinion in manufacturing establishments which are using electric power, it is safe to say that *there is an overwhelming feeling in favor of the use of electrical transmission in preference to the various forms of mechanical transmission on the*

combined score of economy of operation and a reduced annoyance and expense through delays caused by failure of transmission apparatus.

This statement is based upon information given me, directly or through correspondence, by a very considerable number of establishments. The quotations entered above are taken from my correspondence, my choice of letters from which to make quotations being determined by the extent of the electrical experience upon which information given me was founded and the fullness of the information. Few establishments have records from which comparative figures can be obtained, and those which have such figures are seldom willing to have them publicly quoted, but the quotations above show in a general way the results which have been obtained. Every one of the fourteen firms from whose experience I have quoted may be said to be what the Germans would call *Welt Firma.* In nearly every case for which I have exact figures a sufficient direct saving is shown to be effected by the electrical transmission to make large returns on its greater first cost.

5 and 6. *Convenience.* — I will now make a few quotations showing the general effect of electrical power on the convenience of handling product in the shop and its effect upon the output of the shop in the establishments already noted.

A. "We find that we can get a considerably larger amount of product out of a given amount of machinery when it is driven by electric transmission, in addition to the time saved in changing work where overhead machinery can be employed, which was impossible when belting was used." And again, "We are well pleased with our electric transmission and find the economy exists in our being able to transfer the work by overhead cranes—no belts interfering—the consequent amassing of the tools, economy of shop room, avoidance of delays to all the machinery at one time, ease of connections to auxiliary power; in fact, we do not see how we could do business without it. Its use is growing upon us to such an extent that we find it difficult to hold it in check enough to enable us to move cautiously in the matter."

B. See previous quotation.

C. "We do not consider that this method of transmission of power adds at all to the convenience of our workmen, or to the convenience in handling material in our factory, except that in case of breakdown in any part of the factory—that is, any difficulty to the line shafting or any tool or motor—by the use of electrical transmission of power it does not affect any other part of our factory; or if we are desirous of operating one department and not all, we can do so very easily by simply starting the necessary motors and are therefore not obliged to drive unnecessarily a long line shaft, nor operate any tools other than those that we wish to."

D. See previous quotation.

E. See previous quotation.

F. "We have made no comparative tests to determine whether or not we were saving any money by this system of distribution, it being largely with us a matter of convenience as at present operated."

G. Increased output.

H. See earlier quotations. Also, "In response to your inquiry would say that most certainly the driving of our machinery by electricity adds to the convenience of our workmen, inasmuch as it gives them easy and perfect control of the machines. We are driving our machinery somewhat faster with electricity as the motive power than we formerly did when we used mechanical transmission, for the reason that we have quicker control of the machines. We thus expect to increase the product. We might also add that we also expect, although we have not run enough to demonstrate this point, that we shall largely reduce the percentage of second quality of goods produced by our machines."

I. "I am decidedly of the opinion that a shop can be equipped with electrical transmission in such a way as to increase its product very largely over any other mode. I am equally certain that without the electrical transmission that we have in use in our shop that we could not do within 50 per cent of what we are now able to do."

K. "We have not changed our entire factory into the use of electric equipment, but whenever it is necessary to make any changes we invariably drop the old and put in the new idea."

L. "We see no reason why electric driven machinery should show any advantage in the way of convenience over any other system, provided construction is good. So far as the output of our factory is concerned, we do not think it is affected either one way or the other by the system employed." (Compare quotation for establishment L under economy.)

M. "We contemplate in future changing more entirely to electric power. At present a little over one half is covered in this way."

N. "* * * We find the use of generators and motors for certain parts of our power transmission so much handier, neater, cleaner, and more desirable that even though it were not economical from the standpoint of fuel economy we would certainly desire it in preference to line shafting and belting."

O. Apparently no advantage.

Summing up, as before, it is the nearly universal experience that *in establishments turning out a product of bulky or heavy articles the electrical equipment adds materially to the shop efficiency*, a result which seems to be principally due to the convenience which it lends to the arrangement of tools and handling the work from overhead; this not only saves time in itself, but it also leads the workmen to give better service. *In establishments where the product is in small articles* and articles which must be handled in a fixed manner *and where cleanliness is important the electrical equipment adds to the shop efficiency more largely through cleanliness.* This may be a matter of much importance, but ordinarily it is less important than is the question of convenience to the manu-

facturer of heavy or bulky articles. The floor space which can be saved by the use of electrical transmission through a better arrangement of machinery is also much greater in the case of establishments turning out bulky or heavy articles.

7. *Safety.*—The superior position of the electrical transmission with respect to the safety of workmen is evident, and it is not advisable to prolong this paper by entering into a discussion of it here. In regard to the question of fire risk, it is general experience that an electrical plant properly installed is perfectly safe.

8. *Cleanliness.*—This point has been sufficiently touched upon just above.

The experience in all the establishments from which I have been fortunate enough to receive information shows that *for plants using not less than 100 horse power the electrical transmission is so much more satisfactory and economical that it is a misfortune for a new manufacturing plant, except under very exceptional conditions, to be constructed with any type of transmission except the electric.* It is to be understood that the electric equipment should be such that crane motors can be operated from the generators and transmission wires which are laid down for the regular factory power distribution, and, for the best results, the generators should also be adapted to the purpose of factory lighting. These conditions are fulfilled by either a 220 volt continuous current system, using compound wound generators, or by a polyphase alternating current system. In the average manufacturing establishment the former seems to promise the best results, though more experience with the latter may prove it to give equally satisfactory results. The 220 volt continuous current plant allows the use of 220 volt incandescent lamps connected directly between the positive and negative transmission wires, or arc lamps may be used in sets of four.

The status of electrical transmission in plants already built and equipped with mechanical transmission is more complex. Establishments which turn out heavy products, such as locomotive works, engine works, boiler works, machine tool works, iron mills, etc., profit so much by electrical cranes that an electric plant is an invaluable accessory. It is then a natural step to do away with counter shafts and belts running to the larger tools, which may then be equipped for driving by electric motors and placed in a more convenient position with reference to handling the product. This change always results in a large reduction of the cost of manufacturing, and if carried out with caution and judgment is invariably satisfactory. A somewhat similar condition exists in establishments which turn out a bulky product, such as agricultural works, carriage works, etc. The convenient arrangement of machinery which may be gained by using electric motors adds materially to the product that can be put through such a shop, or largely reduces the transmission losses caused by quarter-turn belts, bevel gearing, etc. In the case of a plant of this type upon which careful and complete tests have lately been made by two of my students, it is shown that the actual saving of power, attend-

ance, and repairs now lost in great quarter-turn belts and other features usual in the mechanical transmission system of a somewhat scattered agricultural works, would nearly pay the annual sum necessary to cause a change of the old system into an electrical system to be profitable; while additional convenience in the location of tools, immunity from expensive stoppages due to injured belts, etc., and the advantages of satisfactory illumination gained from the power generator would give a large margin of profit upon the expense of putting in the electrical plant. Establishments which turn out a lighter and less bulky product gain less in convenience from the electric power, but there are numerous industries in which the cleanliness resulting from the suppression of shafts and belts is of the greatest moment. In these, the electrical transmission may be made a great money saver, as is shown by the experience of its users.

There are many special conditions which make the adoption of electrical transmission of advantage in established industries where otherwise it would not pay to incur the expense involved in a change from an established mechanical transmission to a new electrical transmission. Thus, for instance, when an isolated building is located at some distance from the main building of the plant, the expense of operating a separate steam plant in that building, or of conveying power to the building by piping steam from the main plant, or by means of mechanical transmission, is often several times as great as the total annual cost of a complete electrical plant to be used for the purpose. In the total annual cost I include interest and depreciation, as well as fuel, attendance and repairs. A number of cases of this kind have fallen under my observation.

Another case, in which the same result obtains, came under my observation recently. Here the establishment was a large one, with considerable transmission losses (equal to nearly 70 per cent of the average useful load), and a considerable economy in fuel, attendance, and repairs would be effected by replacing the mechanical by an electrical transmission. The large expense involved justly deterred the proprietors of the plant from entering upon the change. The prime power plant of the establishment is now found to be too small to carry the maximum load of the plant with late additions, while the reduced percentage of loss incident in this case to the electrical transmission would enable the engines to carry the load satisfactorily. The complete cost of a change to the electrical transmission is not greatly in excess of the cost which would be required in making the changes in the power plant which would be required for the purpose of adding an engine. These conditions being fully considered, and charging the excess cost, only, to the electrical transmission, the latter would make an annual saving in the cost of operating the works which would well repay for its installation. The electrical plant is here placed upon a basis which is quite near its position with respect to new establishments.

It is unnecessary to multiply similar instances, but I will close by summarizing the matter as follows:

1. In constructing new manufacturing plants, the extra first cost of a complete system of electrical transmission for the works is negligibly small (except under exceptionable circumstances) compared with the annual saving effected by its means when its advantages are properly utilized.

2. In certain industries the advantages of electrical transmission outweigh the first cost of making a change from mechanical to electrical transmission in established plants, while in many plants where this condition would not commonly exist the arrangement of buildings or the growth of the plant is frequently of a character with reference to the prime power plant which places electrical transmission upon an advantageous footing, either as an auxilliary to the main transmission or as a rival to the existing mechanical transmission.

There is one more important question which affects electrical transmission alone. That is the question of the subdivision of power at the machinery. Briefly, the following seems to be the general concensus of opinion amongst those who have operated plants with electrical power: All large tools, such as use from five to seven and one-half horse power and over, should be supplied with individual motors, while smaller tools or machines requiring less power should be grouped and driven from motor-driven shafts. These groups should ordinarily be arranged so that a motor of not less than from three to five horse power capacity is required, and not more than from ten to fifteen horse power. The grouping of tools and subdivision of the power, it may here be said, is a matter which can be given only the most general treatment as a whole, as each industry includes conditions of its own which must be taken into the count.

It may be pertinent to remark at this point that I have excluded from consideration all data obtained from electrical transmission plants in the manufacturing establishments of the electrical companies. There are a half-dozen such plants, several of which are very large, from which excellent results have been obtained, but these must lie under the suspicion of being "show plants." I therefore have confined myself to the results obtained in plants which are entirely independent of the electrical industries.

DISCUSSION.

Mr. Nichol: I would like to ask Mr. Jackson if any of these plants that he has taken have used the electric tool, for instance, the lathe—where it gets into the extreme refinement? I think he has touched on that in general. I would like to know if that is included in the plant?

Mr. Jackson: A great many tools are directly driven through gears or belts, but only in a very few cases are the motor armatures mounted directly on the spindles of the tools.

The Chair: There is a use of electric power in a small way from the manufacturing plant, I believe, driving isolated printing plants

and machines of various kinds, in which the electric power is not derived by the owner or operator of the machines, but possibly from some of the general electric companies. I believe that Mr. Jackson did not cover the merits of that class of machinery in this paper.

Mr. Jackson: In case of printing establishments, the question of cleanliness is so important that in many large establishments they may save thousands of dollars per year by suppressing their belts and shafting, and in such cases they can well afford to equip their larger presses with direct connected electric motors, while the smaller machines can be equipped in groups. This is being done in a great many cases in the East. I do not think of any printing establishment at present in Chicago where it is carried out, but there are many cases in Boston, New York and perhaps Philadelphia where it is done. In some printing establishments that I have seen the establishments own their own steam plants and generate their own current; in other cases they buy the current from the local illuminating companies. It depends upon circumstances whether purchasing from outside concerns is cheaper than the generation of the current in the building. In large cities the generation of from 50 to 250 horse power in a building is a somewhat expensive performance, and it is very frequently that the current is purchased. I believe there are comparatively few that have 250 horse power to buy. The printing establishments have found, as far as I can find out, that electricity is a paying investment, on account of the cleanliness, if for no other reason.

Mr. Coster: I would like to take one little exception to the very admirable paper of Prof. Jackson. He made a statement that the polyphase motor would, in a short time, come up to the direct motor, or something to that effect. Will you kindly read the exact remark?

Mr. Jackson: I will read the exact remark. (Reads.) "In the average manufacturing establishment the former (that is, the 220 volt continuous current system) seems to promise best results through more experience with the latter (that is, the polyphase system) may prove it to give equally satisfactory results." In explanation of this statement I may say that it is an unfortunate fact that I was able to get data from only one establishment, outside of the electrical manufacturing establishments, which was equipped with polyphase motors. The statement came to me from this establishment that the fuel expense is greater now than it was formerly with mechanical transmission (shafts and belts). Experience with polyphase transmissions in manufacturing establishments is so limited that one is forced to the position held in this paper, which position is certainly entirely fair to the polyphase system.

Mr. Coster: I am very glad you are so fair. I will tell you why it cost more to operate this particular plant: These people put in an experimental plant to test the reliability of electric power; they work it in connection with their steam plant; they have not put in sufficient power to enable them to shut down the other steam engines. I saw the vice president of the company, and he told me he would

have enlarged his plant considerably this year if it had not been for the financial condition of the country and the uncertainty before the presidential election; also that he surely expects to extend very largely next spring. I would like to enlighten Prof. Jackson in a few very brief remarks, and tell him some of the decided advantages of the polyphase system over the direct current system. First of all, the motor has no brushes, commutator or collector of any kind; this is the very last type of motor which the Boston and Maine R. R. are installing in their new shops at Concord, N. H. Secondly, you can obtain a motor which is much more efficient at less than full load than any direct current motor that is manufactured. Third, you have a system which, owing to its flexibility, has practically no limit to the distance of transmission within 15 or 20 miles. There are many more, but I do not wish to take up your time at present. These are some of the principal advantages, and it is plain that they are very important ones.

The Chair: We would like to hear further on the subject, either from Mr. Coster or from any other gentleman present that can discuss the matter. Mr. Arnold, could you say anything on that subject?

Mr. Arnold: I can not say that I am quite so sanguine about the polyphase motor for this particular application of the work. I do think it has a very large field, where the motor load is practically constant, or where it is not necessary to start it and stop it too often. I won't say that it might not be for such cases as Prof. Jackson has mentioned, but I have not had sufficient experience with it to know from my own judgment. I have put in a number of power transmission plants in factories for distributing power with direct current, and am getting good satisfaction with it. I am now installing in a printing establishment printing machine motors and printing presses. I also equipped a factory about a year ago, where I thought the conditions were very nicely created for the adoption of electric transmission by the burning of the old factory, which was built on the belted principle. We rebuilt the plant on electric lines, and he seems to be very much pleased with it.

I wish to take one exception to the statement Prof. Jackson made, which he has since modified, so that it need not be considered a criticism, which is to the effect that it will pay you to buy power for small establishments. I believe he put the limit up to 250 horse power. In any plant over 150 horse power you can produce the energy, in my judgment, for less money than you can afford to buy it, because you almost invariably have to heat the building, and you must have a boiler plant. You have got to have an engineer to run the boiler plant, according to the city license, therefore you are saddled with the expense of engineer, and probably a fireman. That being the case, you can operate an electric plant with little additional expense, possibly two men and the cost of fuel for producing the extra power, and you also have the advantage of being able to utilize the same steam you make the power with for heating the building. That is the case we have in the Board of Trade here. Now, under

those conditions, I think it is perfectly evident that you can produce your own power for less money than you can buy it, because with suitable additions, I mean with a plant of that sort or a little larger, with fuel at $3.00 a ton, you can produce a kilowatt hour and put it on the switchboard for about a cent and a quarter. That being the case, you can not afford to buy energy at from five to seven cents per kilowatt hour. I do not mean to say that I can produce it at that price, including wages and everything, as this is only the fuel expense, to which you must add the interest and whatever attendant's wages should be charged to electric plant, which, by the way, you carry in the building any way. To do that would probably bring the cost up to three and one-half cents per kilowatt hour, and you can not usually buy it for less than five to seven cents per kilowatt hour.

Mr. Nichol: I would like to ask Mr. Arnold if the question of liability would not enter into that matter? That is, is there not less chance of accident and stoppage when taking it from the central station than when producing it from a comparatively small plant, and then, in addition to that, the space occupied in the printing office, taking in the center of the city, floor space is very valuable, in most cases it is chuck full of printing presses, so that there would be very little room for the steam plant and engine and dynamo.

Mr. Arnold: I do not think space is sufficiently valuable to prevent your occupying it for power. It is a question whether you want to buy it or whether you can generate the power yourself. The other point of always being attached to a central station is easily answered by the statement that we can design any plant on a certain system, whereby you can have a main switch capable of connecting the plant instantly with the central station, and you then have the central station to draw from in case of accident. That is one way. The other is to put in a duplicate engine or dynamo. Either one of these plans will meet the emergency.

Mr. Arnold: There was one thing I failed to say about the railroad question. I do not want the meeting to adjourn without setting myself right on it, and that is, that it is not going to be entirely a question of economy that is going to govern the equipment of steam roads with electricity; it is going to be a question of what is demanded by the patrons of roads on suburban service, and a case of railroads protecting themselves against competition with the trolley, therefore I expect a very marked increase in the near future in the application of electricity to steam roads. The demand of the traveling public then is what is going to bring the pressure, instead of very marked expected economy which is going to be effected in the consumption of fuel. There will be great economy to the roads in saving of labor, and that will pay the roads, but it will not come in the shape of fuel economy, except in special cases, as much as in the saving of labor. With these elements working in favor of electricity, it is fair to presume that the steam roads will equip short lines for suburban service as promptly as possible, and gradually extend the system by reducing the weight of their trains and running more of them, thus approaching the conditions favorable for electricity until

a large number of the lines will become equipped electrically throughout their entire length, and especially and speedily will this be effected if the efficiency claimed by Dr. Jacques can be realized in practice.

Mr. Gibbs: Mr. Chairman, I hope Prof. Jackson will feel justified, in the publication of his paper, in at least giving the class of manufacture referred to in each letter he quotes. If he prefers not to say definitely whether it is, for instance, a locomotive works or a cotton mill, if he will say "heavy" or "light machinery" it will be some guide in drawing useful conclusions. I recognize one of the establishments, that having about 1500 horse power of motors, and I was informed the other day at their works that the cost of repairs on electric motors—they have got 140—was considerably less than the former cost of belt repairs, and they are very much pleased in every way with the adaptability of electricity to shops manufacturing heavy machinery. The gain in appearance in their shops is really marvelous; it cannot be appreciated without seeing it. In two or three shops they have one-half run by electricity and the other half by the old belt transmission, and it is like going from night to day, coming from the belted department to the motor driven department. And I will say further, that they have adopted a plan which I consider a good one from a mechanical standpoint, of connecting their motors by short belting to the tools. This gives a flexibility in starting and stopping and relief from sudden strains; it is, in fact, a good mechanical proposition. I have seen, and we have discussed a good deal, the proposition of connecting motors into the head stocks of lathes by direct gearing, also of using motors direct connected without gearing. This can be done, but there does not seem to be any electrical or mechanical sense in doing it, and economically it is an absurdity, for in the case of an electric motor, as in a steam engine, the first cost will increase as the speed decreases.

In the locomotive shops we have not been able to go into electric transmission to any great extent yet, for the reason that the railroads have not been inclined to take up avoidable expenditures during the past few years. I do not expect, therefore, to see much development in this line until business improves. In our shops in Milwaukee we have outlined a number of applications that can be made to great advantage. One we have lately made may be of interest. We had an old walking crane, which ran on a single track and was propelled by a cotton cable running at a very high velocity, and which cost us a great deal for repairs. We found, by taking the current readings of a motor temporarily connected to the rope countershaft that it took 15 horse power to "idle" the rope and only two additional horse power to lift the weight, or traverse the crane. We applied, at small expense, two steel-clad motors of 3 horse power each to the crane, one for traversing and one for hoisting, and it has been operating to our perfect satisfaction for the past six months. We estimate we will pay for the equipment in cost of power saved in one year.

ABSTRACTS OF PAPERS IN FOREIGN AND AMERICAN TRANSACTIONS AND PERIODICALS.

MACHINERY BEARINGS.

By John Dewrance, Assoc. M. Inst. C. E.

(*Proceedings of the Institution of Civil Engineers; Vol. CXXV., p. 351.*)

In this paper are presented results of a series of experiments undertaken by the author to determine the frictional resistance of shafts revolving in bearings under varying loads, when subjected to different conditions. Illustrations are given showing the style of testing machines used.

The journals upon which the experiments were made were 10 inches and 4 inches respectively in diameter, and formed part of a shaft supported at its ends in plummer blocks. A saddle rests upon the upper bearings and is connected through four bolt compressing springs to a plate pressing upon the under side of the lower bearing. The load carried by the journal can therefore be varied with the degree of compression of the springs, the pressure upon the upper bearing being greater than that on the lower by an amount equal to the total weight of the saddle, spring and bearings, generally about 16 cwt. It was not convenient to apply a thermometer to the lower bearing, so the observations were usually confined to the upper one, which, having to support the greatest load and being at a disadvantage as regards lubrication, generally failed first. When the saddle had been fitted with a pair of bearings the four bolts were evenly screwed up, the amount of compression being indicated by scales and pointers, on each side. When loaded the saddle was free to turn with the shaft through a certain range, and a spring balance, fitted to retain the saddle in a vertical position, indicated the amount of force required to turn the shaft.

The first experiments were made upon a pair of 10-inch by 16-inch bearings having two oil holes on the top center line. They were carefully fitted about 1-64 inch larger in diameter than the journal, but they would not run cool with the weight of the saddle alone. When a channel was made to connect the two holes and to lubricate the part of the bearing between them, the result was not greatly improved. When oil was thrown upon the shaft at the openings between the bearings they began at once to sustain loads more or less satisfactory, but the oil issued from the holes at the top. The pressure indicated on a gauge connected to the center of the bearing was equal to the greatest load that could be applied to the large bearing; the experiments were, therefore, transferred to the 4-inch shaft with a bearing upon which the same load represented a

greater pressure. A long series of experiments resulted ultimately in a pressure of 2,300 lbs. per square inch being recorded. The bearing was taken out and the surface dressed with a view to obtaining even greater pressures. When, however, it was replaced the following day, instead of continuing to deliver oil at gauge connection as hitherto, the bearing would take oil rapidly. The pressure gauge was removed and a vacuum-gauge substituted when it was found that a vacuum equivalent to 30 inches of mercury existed where previously a high pressure had been recorded. The bearing still ran cool and well, as shown in table I of the appendix. When taken out there was nothing in its appearance that at first sight accounted for the change described, but further examination revealed that, although the back of the bearing had been planed, it was from some cause, not quite flat, the center of the bearing taking all the load. This had sprung the bearing slightly and had worn the central part of the surface. When the load was removed the center sprang back, leaving that part of the surface round the hole separated from the shaft. The load applied during subsequent experiments had not been sufficient to spring the bearing flat again. The experiments on this point were continued until a bearing was produced that, when placed on the shaft one way, gave a pressure in a hole at the center of the bearing and, when reversed, gave a vacuum at the same point. As a result of the observations made during the foregoing experiments an arrangement was set up which is shown

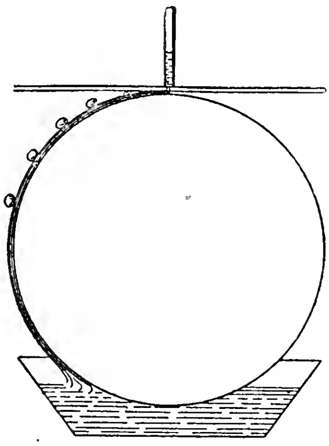


Fig. 192.

diagramatically by Fig. 192 to illustrate the way in which oil lubricates a bearing. If oil is slowly poured on a revolving shaft, it accumulates in a thick ring, most of which can be wiped off by hand. The oil next to the shaft adheres more firmly than that which is further away. If the oil ring be imagined to be composed of films of oil, each of the thickness of a molecule of oil, the first film has the solid shaft to adhere to. The second is separated from the shaft, but it can adhere to the first, which is itself firmly held. Each sucessive film is less influenced by the force of adhesion that exists between the shaft and the oil, until the point is reached at which centrifugal

force is stronger than the adhesion and the oil flies off the shaft. If the shaft be rotated in a bath of oil, the ring of oil is also formed. In Fig. 192 the circle represents a shaft, on the top of which a flat plate rests. However light this plate may be, it affects the ring of oil immediately it touches it. Unless the plate entirely stops all the oil from passing round with the shaft it must float upon that part of it which remains between it and the shaft. There must be, in other words, a film of oil at a sufficient pressure per square inch acting on the narrow surface of contact to support the total load upon the plate. This pressure is the result of the multiplication of the force of adhesion of the oil to the shaft by the inclined plane formed by the plate to the shafts. The velocity of the oil is also increased in the same way. If the load on the plate is a light one the adhesive force is sufficient when increased by the inclined plane, to produce a pressure required to lift the plate and carry several films round with the shaft; but, as the load is increased, fewer films are able to pass the plate until the point is reached at which the surfaces abrade one another for want of lubrication.

If a hole is made through the plate, this pressure can be observed, increasing as the hole approaches the point at which the plate rests upon the shaft. If the hole is pushed beyond this point a vacuum is produced. The oil and air in the hole adhere to the films and are carried round with the shaft by surface adhesion. A flat plate was employed in this experiment, as it was easier to observe the relative position of the hole. The conditions are not greatly changed if the diameter of the shaft be reduced and the plate curved. A bearing that exactly fits the shaft all the way round will not run cool, and the well known fact that a bearing must not be tight at the side indicates that the inclined plane must exist in some form or other. All successful bearings are constructed with an inclined plane in some form, and the load that a bearing will sustain is determined by the inclination. If the angle is sharp it will not multiply the adhesion of the oil so much as if it is more gentle. By suitably adjusting the inclination it has been found possible to pump oil between the surfaces to a pressure of as much as 3,000 lbs. per square inch.

These experiments were originally instituted to demonstrate whether with similar lubrications and conditions a bearing surface composed of one alloy would allow a greater load than a bearing surface of another alloy, and they have proved that it will not. The composition of the metal of the bearing surface has little or no influence on the load that the bearing will support. Bearings composed of a metal that may, under certain circumstances, seize at a pressure of 20 lbs. per square inch, have been run with a load of more than 3,000 lbs. per square inch, and many different kinds of metal have been used in bearings that have run loaded to more than one ton per square inch. At these loads the lubrication becomes so uncertain and difficult that the point at which it fails is due to conditions that cannot be observed. In no case was there the slightest evidence that this point was reached sooner with one alloy than it was with another, so long as the metal itself would support the

load. The experiments leave no doubt that so long as a bearing runs fairly cool the surfaces of the shaft and bearing are separated by a film of oil. If the number of films is small it is possible to have considerable heating without actual seizing, but if the films of oil are entirely absent the surfaces adhere or seize at once. The simplest example of this kind of adhesion is afforded by the abrasion of an iron surface by a piece of brass. The crystals of the iron tear out crystals from the brass. By burnishing the iron surface its tendency is reduced to a minimum, and by corroding the surfaces chemically it is increased to a maximum. If the pressure and speed are low, a great deal of brass can be torn from the high places of a bearing, especially if there is a good supply of oil.

When a bearing that has worn to a surface is allowed to rest upon the shaft without the intervention of a film of oil, and the crystals of the bearing adhere to the shaft, they must make an elevation on the shaft that would prevent it being turned except by a force sufficient to lift the load on the bearing to the height of the elevation due to the crystals. This would concentrate the whole load on this elevation, with the result that more crystals would be dragged out. If the load is very great, say more than 1 ton to the inch on an 8-in. by 4-in. bearing, seizure has occurred with a suddenness almost startling; but the presence of oil in some parts of the bearing, and the lower loads used in practice, generally make the seizing more gradual.

A piece of iron will not leave a mark upon the surface softer than itself; it becomes coated with the softer metal. If the bearing is of material of which the crystals are individually stronger than those of the shaft, the crystals of the shaft adhere to the bearing, which, being stationary, causes the crystals to be heaped up in one place instead of being carried round and spread over the whole circumference of the shaft. This is the reason that the seizing of a cast iron bearing is often attended with such disastrous results, and there can be no doubt that the softer the metal of the bearing the safer is the shaft from injury from seizing. Many hundreds of experiments were made upon the machine with soft metal bearings without injury to the shaft, but when similar experiments were made with hard bronze bearings the shaft was several times injured and had to be turned.

It is possible under some circumstances to provide sufficient lubrication without intermission. When this is the case, the shaft revolves in oil, and it is surprising with what a small power a heavy load can be supported, and how small the destruction of the surfaces may be under these conditions, as shown in Table XLII. of the appendix. It is well known that even when the lubrication has been continuous the surface of the bearing has suffered considerably, and in some cases the surface of the shaft. If it is accepted that as long as a bearing works cool and shows no sign of seizing, the surface and shaft are separated by films of oil, it is at first sight difficult to see how either metallic surface can wear away. In some cases the oil contains grit which is carried between the surfaces and

scratches them. It has been proved on the testing machines that dust that will float in a quiet atmosphere is usually less in bulk than the thickness of the film of oil. Had this not been the case the experiments could not have been conducted where they were, as the machine was exposed to a considerable amout of floating dust.

The corrosive effect of the oil itself on the surfaces does not appear to have been hitherto recognized. It was first observed when experimenting with a pair of bearings of pure lead upon the 10-inch shaft. Olive oil was used, but after passing through the bearings several times, it became black and thick. This oil, after filteration, was composed of 16 per cent of oleate of lead, 9.57 per cent of oleic acid, and 74.62 per cent of olive oil and glycerine. Oil of the same quality was then run through the bearings composed of hardened tin, which were found to be but little affected. Disks of the metals used in the manufacture of bearings were immersed in oleic acid, and occasionally drawn out of the acid so as to be exposed to the air. Lead and zinc rapidly corroded away; copper was corroded, but to a less extent. Tin and antimony were not appreciably affected. Oleic acid appears to attack lead, zinc and copper with great avidity. Even if the oil is free from acid it becomes charged with oxygen from the atmosphere which oxidized the surfaces, the oxide itself being immediately carried away by the oil. A great number of experiments showed that a bearing composed of an oxidizable metal, such as hardened lead, could be worn and scraped to a surface corresponding to the shaft in a quarter of the time required to produce the same effect on a bearing composed of hardened tin. For this reason a number of the special forms of bearing were made of hardened lead. Hardened zinc was tried in one instance, the bearing being tested by hydraulic pressure after the usual pressure gauge holes were drilled and oleic acid being used as a lubricant. The acid attacked the surface so rapidly that instead of improving it it became worse as time elapsed. Oil was then used, but when the surface had arrived at the point of delivering it at pressure, it was found that the oleic acid had soaked into the pores of the metal and so corroded it that the oil oozed out all over the bearing at very slight pressure. The alloys of zinc are probably the most crystalling used for bearings, and there seems to be no doubt that the size of the crystals greatly affects the rapidity of chemical corrosion. This open grain or crystalline structure occurs more or less in all bronze castings and renders these more subject to chemical corrosion than would otherwise be the case with an alloy of copper and tin. The chief recommendations of bronze as a material for bearings are its high melting point and its capacity of resisting high compressions. The melting point of the tin alloy is 500 deg. F. The alloys of lead and zinc vary more than the tin alloys, but their melting points are not much higher. With suitable lubrication bearings should run cool; if the temperature rises above 200 deg. the viscosity of the oil is so much reduced that the bearing will probable seize. There is considerable opinion as to whether a bronze bearing will behave better than a tin bearing under such circumstances. The

bronze bearing will, if allowed to run after it becomes heated, almost certainly injure the shaft, but the tin alloy bearing will run till the temperature reaches 500 deg. without injury to the shaft. Higher temperatures than 500 deg. are dangerous, and with proper arrangements ought never to occur. The compression test deserves more consideration than it has hitherto received. Many of the alloys of tin and lead now used to line bearings have so low a compressibility that they yield under the ordinary pressures applied to bearings with the result that the metal squeezes into the oil inlets and stops lubrication. This circumstance is no doubt responsible for much of the trouble that has been experienced with the use of alloys of this class. It is suggested that no alloy should be used until it has been demonstrated satisfactorily that its point of first yield is considerably above the greatest load or shock to which it will be subjected in use. The method of making such a test is very simple. A bush four inches in diameter by three and one-eighth inches bore, giving an area of metal of five square inches is cast on a chill and is placed in a hydraulic press. A line is drawn on the side with a pair of compasses set to about three inches radius. The bush is loaded by successive increments of one-fourth ton, the load being taken off each time. When it is found that the line drawn by the compass thickens the previous line the metal has yielded. Even after this point, different alloys behave very differently, some taking a large increase of load to cause a yield of one-eighth inch, others continue to yield very fast after they first start. It is possible to make an alloy of tin that will not yield in this way until loaded to eight tons per square inch. The author's experiments suggest the following rule: The oil should be introduced into a bearing at the point that has to support the least load, and an escape should not be provided for it at the part that has to bear the greatest load.

All the most important bearings belong to one of three classes—(A) those having a continuous load in one direction, (B) those having an alternating load in opposite directions and (C) those with both a continuous in one direction and an alternate in opposite directions.

In class A is included the ordinary mill bearing or plummer-block used for supporting shafting. The oil is fed into the center of the top bearing at the point that has to bear the least load, so that in this case the rule is conformed with. This class also includes railway carriage bearings. These were originally lubricated by holes through the crown of the bearing at the point of greatest pressure. It was, however, found that the lubricant would not enter at that point until the surfaces were more or less roughened. These bearings are now invariably lubricated according to the rule given. Foot steps of vertical shafts and thrust-blocks of marine engines belong to this class, but no experiments were made upon them.

In class B are included the bearings of vertical engines. The bearings of a marine engine resemble the ordinary plummer-block, and in the shaft tunnel their duty is the same; but those near the connecting-rod have an entirely different duty to perform, which is the same as the connecting-rod bearing. The oil is generally applied

at the center of the top bearing in defiance of the rule. If the oil-hole is left plain it is found that no oil will enter during that part of the stroke when there is pressure on the top half of the bearing. To meet this difficulty oil-channels are cut. It must be evident that as the pressure of oil between the surfaces gradually increases from the point of least pressure to a pressure equal to the load at the point of greatest pressure, channels that run circumferentially around the shaft must be bad, unless they are confined to the part of least pressure. Their effect is to scrape off the oil at the point of greatest pressure and deliver it unused at a point of less pressure. The re-

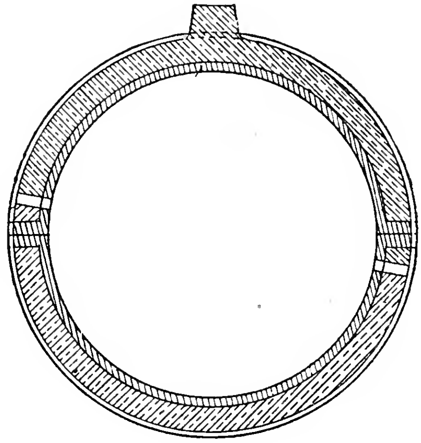
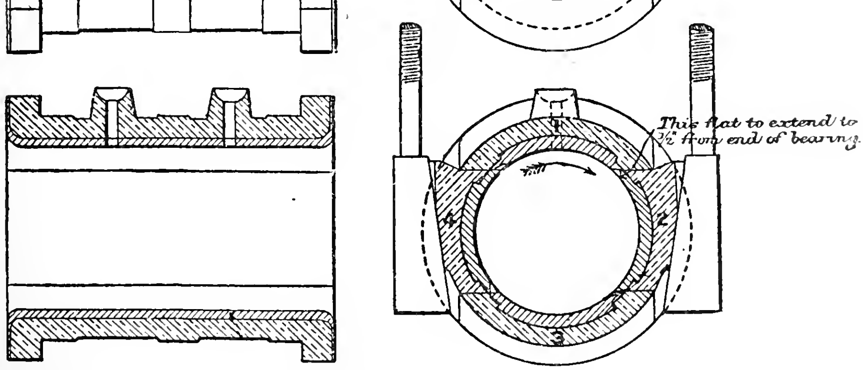


FIG. 193.

sult in the ordinary marine bearing is that the oil delivered into the bearing runs down the channels as far as possible and is not used on what might be called its first journey through the bearing. It is then taken up by the shaft and is carried to the second half of

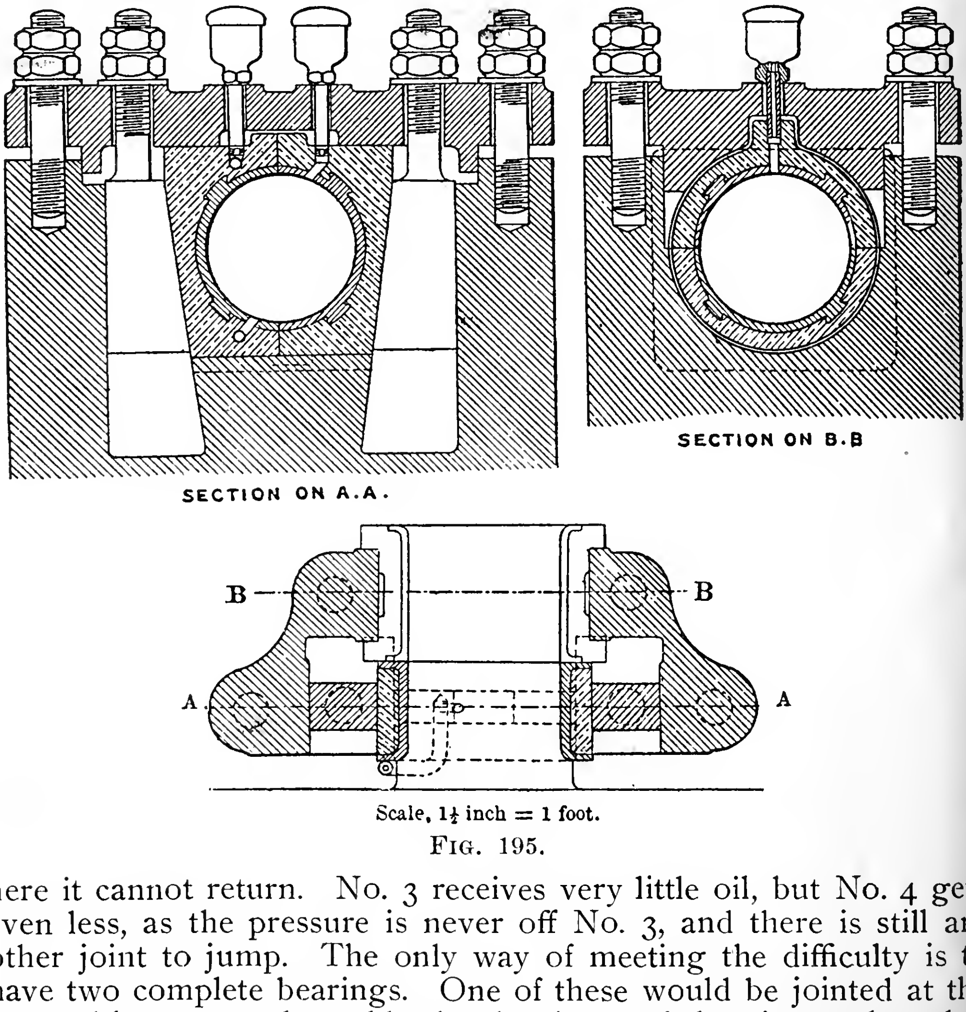


Scale, 1½ inch = 1 foot.

FIG. 194.

the bearing. The proper point to introduce the oil is just above the joint of the bearing at the side. There the oil is distributed over the shaft and carried to the point of greatest pressure. As there are no channels from this point the oil cannot escape and will support almost any load. There is no reason why one bearing only should be lubricated in all large bearings; it is desirable that each half should have its own supply of oil. (Fig. 193.)

In class C are included the bearings of horizontal engines, especially the main bearing next the connecting-rod. This is the most troublesome kind of bearing, as it has double duty to perform. To facilitate the taking off of the wear, the device shown in Fig. 194 has been used. The bearing is in four parts, three of which can be drawn toward the center. The oil is introduced at the top at a point of least pressure, but before it arrives at the first point of greatest pressure, it has to jump a joint. At some parts of the stroke, it cannot do this, as the load is too great, but at others it can, and it is then carried into bearing No. 2. Before it can reach No. 3 it has another jump greater than the last, because when the oil escapes



Scale, 1½ inch = 1 foot.

FIG. 195.

here it cannot return. No. 3 receives very little oil, but No. 4 gets even less, as the pressure is never off No. 3, and there is still another joint to jump. The only way of meeting the difficulty is to have two complete bearings. One of these would be jointed at the top and bottom, and would take the thrust of the piston; the other would be jointed in the opposite direction, and would take the

weight of the shaft and fly-wheel. Such a bearing is shown in Fig. 195. It is very important that the oil should be fed at a point exactly central in the length of the bearing. If it is fed a little to one side the oil separates the surfaces and tilts the bearings, the consequence being that the oil is forced out at one end too fast, and at the other end the bearing is probably running dry.

The sides of the bearing should be carefully eased off, and should slope toward the center to bring the oil that escapes from the other half toward the center. Channels in the bearing or the shaft-surface can do no good except as receptacles for the debris when the bearing seizes. Such an advantage is very doubtful, but if they are used for this purpose they should be in a line with the shaft, and not pass round it. They must not extend more than three-quarters the length of the bearing.

When it is fully recognized that a bearing will sustain a load exceeding one ton per square inch and that most costly and serious troubles are experienced with bearings that are loaded only to a twentieth of that load, it must be admitted that the subject requires investigation. The author hopes that this paper may in some small degree have the effect of suggesting new channels of thought and experiment that may add to knowledge on a subject of such great importance.

APPENDIX.

TABLE XLI.—RESULTS OF EXPERIMENT LVI.

Time.	Total Load on Top Bearing.	Temperature.	Total Tangential Pull.	Time.	Total Load on Top Bearing.	Temperature.	Total Tangential Pull.
Minutes.	Lbs.	°F.	Lbs.	Minutes.	Lbs.	°F.	Lbs.
....	5.376	98	....	80	32.906	230	470.0
10	5.376	113	80.0	90	37.632	242	400.0
20	7.706	116	115.0	100	42.470	245	350.0
30	12.723	128	155.0	115	42.470	242	400.0
40	16.934	134	157.0	125	42.470	262	400.0
50	19.264	154	215.0	135	42.470	264	400.0
60	23.834	220	400.0	145	42.470	258	350.0
70	27.552	182	350.0	150	47.846	280	470.0

Area of bearing surface of top bearing=$2\frac{1}{2}$x8 inches=20 square inches; bearings lubricated with sperm oil. Diameter of shaft, 4 inches; speed, 266 revolutions per minute.

After having run for 150 minutes, bearing was taken out; its bearing area was highly polished at the ends, and seemed to have seized at the middle

EXPERIMENT LVIII.

The same bearings were used as in Experiment LVI, and they were lubricated with sperm oil and pads. The total load on the bearing was 15 132 lbs. =756.6 lbs. per square inch. A vacuum gauge connected to the center of the bearing showed a vacuum of 28.4 inches of mercury, the barometer standing at 30.2 inches.

TABLE LXII.

Time.	Temperature. L. H.	Temperature. R. H.	Load.	Tangential Pull.	Time.	Temperature. L. H.	Temperature. R. H.	Load.	Tangential Pull.
	° F	° F	Tons.	Lbs.		° F	° F	Tons.	Lbs.
7.30	127	127	18.96	115.5	12.0	145	139	18.96	95.0
8 0	136	132	18.96	115.0	12 30	146	139	18.96	95.0
8.30	138	134	18.96	115.0	1.0	146	140	18.96	95.0
9 10	96	96	4.6	60.0	2.10	98	98	4.6	95.0
9.30	128	125	18.96	110.0	2.30	130	130	18.96	105.0
10.0	135	131	18.96	102.5	3.0	134	134	18.96	100 0
10 30	138	133	18.96	100.0	3.30	137	137	18.96	95.0
11.0	140	137	18.96	100.0	4 0	138	138	18.96	95.0
11.30	143	138	18.96	95.0	4.30	140	140	18 96	92.5

Area of bearing-surface of top bearing=18 square inches; bearings lubricated by pads hung on either side of the shaft and feeding neat's-foot oil by capillary attraction. Diameter of shaft. 4 inches; speed, 266 revolutions per minute.

THE SUBSTITUTION OF ELECTRICITY FOR STEAM IN RAILWAY PRACTICE.

By Louis Duncan.

(*Transactions of the American Institute of Electrical Engineers, 1895, p. 374.*)

In order that it may pay in practice to alter the motive power of a railway, it is necessary that the receipts must be increased or the expenses diminished by an amount rather greater than the interest on the first cost of the change.

The author quotes statistics to show that the tendency is to run shorter and more frequent trains for passenger traffic, while for goods traffic the opposite practice of having heavy trains with a single locomotive has grown up, the weight per train-mile having more than doubled between 1870 and 1890. For the former class of traffic electricity is eminently suitable, since the conditions imply a distributed load with a maximum demand not greatly exceeding the average load, the cost of generating plant and mains being therefore low; while with steam, the increase in the number of locomotives leads to much greater expense, it being stated that doubling the number of engines increases the working cost 50 per cent. With goods traffic the conditions are exactly reversed, a single locomotive of large power being economical, while the cost of electric traction is great, the irregular distribution due to the few and heavy trains entailing a larger capacity for the mains, and if several generating stations are employed for the stations, and even if only one station working at high tension is used, although by this means its capacity need not be augmented, that of the transforming devices must be increased. The author does not consider it possible to devise any more economical method of dealing with goods traffic, and the difficulty of introducing a change would be greatly enhanced by the large amount of through traffic which, as in a case cited, may amount to 46 per cent of the total

goods mileage. This class of traffic is of great importance, since the revenue from it on all lines of the United States is from two and a half to three times as great as that from passenger traffic.

Since, in the author's opinion, it would not pay on trunk lines to make any change as regards goods traffic, he considers the question of utilizing partly steam and partly electric traction, and details his reasons for arriving at the following conclusions: For a through-line with two tracks, having through as well as local traffic, it is not advisable to employ electricity on the main lines. When there are four tracks, if the line connects the two cities which are termini for all passenger traffic, by equipping all tracks the express service could be run at short intervals on two, while goods and local trains could run on the other two, the local trains being electrically propelled. When, however, there are a large number of through cars from other lines, the conditions are not so favorable for the express service. For branch lines the question depends on the length and frequency of service; if the line is short and there is considerable passenger, but little freight-traffic, electricity is preferable, but not otherwise.

The author draws attention to the great danger to railway companies of the local traffic being diverted to electric tramways running between the same points as the steam lines, the tramways having the important advantage that they traverse the city and extend in all directions in the suburbs. On some branch lines he thinks that it would be advisable to use single electric cars running on the steam lines between towns and on the tram-lines locally, a number of motors being used to allow of their grouping being varied according to the permissible speed and the pressure of the supply. As regards the particular electric system to be adopted, he thinks that trolley lines with continuous currents are the most suitable and reliable, different pressures being used in towns and on the lines between them. For very long lines the working current should still be continuous, but it might be supplied from rotary transformer sub-stations, fed by alternating currents. As an alternative, a two or three-phase system, with rotary field motors on the cars, might be adopted, in which case he suggests that different periodicities should be used in towns and on the lines.

The author passes on to the case of new lines built especially for electrical working; these are generally used almost exclusively for passenger traffic, and the most favorable conditions for this system, therefore, exist. Referring to the New York underground line, the author thinks that about 150 trains, each with one motor car hauling five ordinary cars, will be required for the local service, and twenty-five trains, each with one motor car and four trailers, for the express. Direct current, distributed on the three-wire system, would be the best, the chief reasons being that with four motors on the car, all necessary speeds could be attained economically by varying their grouping, and a large amount of energy lost in stopping could be restored to the line; this is of great importance in a case of the local trains, since the amount of energy that has to

be got rid of in stopping so frequently is very large, and the author thinks that with motors of ordinary efficiency, about 45 per cent of the energy can be returned. He advocates the use of batteries, to give a uniform load to the generating station, the capacity of which may in this way be reduced to almost one-half that which would be necessary were the energy not returned. The objections to the use of alternating current for lines like the one in question, are the impossibility of restoring the energy and the difficulty of varying the speed. For elevated roads the same system would be best; existing structures would require the use of shorter trains.

A railway scheme of the Baltimore & Columbia Railway Company is referred to, in which ordinary speeds are to be used in the city, and speeds of 60 miles per hour outside it, and a good many problems will have to be solved, among them that of providing an underground conduit in the District of Columbia, trolley lines not being allowed therein.

The author concludes with a description of the Belt line tunnel, which runs for a distance of one and one-fourth miles beneath the city of Baltimore, the line continuing to the outskirts of the town through cuttings and short tunnels; the gradient is 1 in 125 in the greater part of the tunnel, and one-half mile beyond it is 1 in 67. The difficulty of ventilation has led to the provision of electric locomotives to haul the trains, steam engines included, over this portion of the line. There will be three of these locomotives, but two will ordinarily suffice; they will run over about three miles of line, and will assist the goods steam locomotives to haul the trains up the incline outside the tunnel. The current is conveyed to the motors by means of an overhead line, which is placed between the tracks at a height of 22 feet from the top of the rail outside the tunnel and 17 feet within it, there being insufficient head-room for the ordinary arrangement. The conductor is formed of an iron trough, made up of two Z-bars, riveted to a cover-plate 12 inches wide, leaving a slot one inch wide between the bars; they are in 30-foot lengths, riveted and bonded together. The trough is carried by channel bars, hung from expansion bolts fixed in the top of the tunnel, and from catenaries, supported by iron columns 150 feet apart outside. Copper cables are used as feeders, and one serves to increase the conductivity of the return circuit. Contact is made with the trough by a brass shoe traveling within it. Current is supplied from generators giving 600 volts at no load and 700 volts at full load, coupled direct to 750 H. P. Allis-Corliss engines. The locomotives have eight driving wheels, and weigh 95 tons each.

GOVERNING OF WATER POWER UNDER VARIABLE LOADS.

(*American Society of Civil Engineers—Proceedings Vol. XXII., No. 8.*)

By M. S. Parker, M. Am. Soc. C. E.

The government of water power under variable loads has always been considered a difficult problem under the most favorable conditions. Many operators of water power plants where changes in load are great and sudden have found their government so uncertain and near the danger line that it was believed a few years ago that small electric street railway plants could not be successfully operated by water power. With large plants the change in load represents but a small percentage of the whole power in use so that the variation in the load is not so extreme as to cause serious difficulty in the government of the power. It is the extreme and sudden change that causes trouble.

The modern ball governor, as used to regulate water wheels, is satisfactory in its operation where the power used is fairly constant, but becomes entirely inadequate for the government of water power where the changes of load are sudden and extreme. The author had this problem of the government of water power brought to his attention a few years ago and found little published data to assist him in solving it. The solution became a matter of experiment.

The power to be governed consisted of a pair of $22\frac{1}{2}''$ Victor turbine wheels working under 40-ft. head. These wheels generated about 400 H. P. on the wheel shaft which is used in operating 6 miles of electric street railway, having a 20-minute service. On this line are employed from four to ten cars daily, equipped with two 15 H. P. single motors. Extremes of variable load are of daily occurrence. There are moments when with four or more cars in service the load is suddenly removed by the stopping of all cars at once, making a sudden change from a load of 120 H. P. or more to no load on the generators.

This was the cause of frequent annoyance and expense due to the burning out of armatures, as the ball governor of the water wheels does not act quickly enough to prevent racing of the wheels at times. A large fly wheel roped with five 2″ diameter ropes from the wheel shaft failed to hold the wheels always in check. When the wheel governor assisted by the balance wheel, succeeded in checking the speed, as frequently occurred, the recovery of the necessary power to operate the entire load was necessarily slow in action, causing delay in the starting of the cars. The water to operate the wheels mentioned is conducted from the head works at the dam to the wheels through a penstock 9 ft. in diameter and 400 ft. long. The absence of a vent or standpipe on the penstock made the problem of government of power still more difficult of solution. It has been the practice among hydraulic engineers so far as the author is aware, to disregard length of penstocks in designing water power plants. From the author's observation and experience it is

shown that the shorter the column of water in the penstock, the easier it can be regulated or governed in flow at the wheel; in other words, in reducing the time of getting power from the water to a minimum where long penstocks are indispensable it will add greatly to the facility of governing the water if a standpipe is placed on the penstock near the wheels to be governed, of a diameter equal, or nearly so, to that of the penstock. The vent pipes as generally used on such penstocks are entirely too small to be of any material service in governing the water power developed.

A patented electric governor was obtained and has now been in operation for about two years and has proved successful beyond all expectations. This electric governor consists of a gate regulator, a high speed engine regulator and a common telegraph or gravity battery, with its circuit. The regulator is powerful enough to control the wheel gates, and receives its power directly from the wheels. It is also so sensitive that the battery current will cause it to move the gates as desired. The engine governor is simply used as an indicator of speed and as the indicator rises or falls it makes an electric contact, telegraphing the regulator which way to move the gate. This governor is not an expensive piece of mechanism. Its construction is simple. The expense of maintenance for the time it has been in service has been nominal. While the author is not prepared to say that this is the best device on the market for the government of water power under variable loads, he can say that it is the best and least expensive device that has come to his notice, and that it has solved the problem of the government of water power under extreme variable loads in the instance herein cited.

The paper gives illustrations of the governor and cards of daily records.

THE EFFICIENCY OF HYDRAULIC DREDGING.

A. W. Robinson, in *Cassier's Magazine* for November.

The efficiency of a hydraulic dredge, considered as a machine for raising mud and earth, is very low, but, taking the total result and comparing it with other methods of doing the same work, it presents great advantage. The efficiency of a good centrifugal pump for water is from 55 to 65 per cent under ordinary conditions; that of a dredging pump is necessarily somewhat less being from 48 to 55.

Let us take, for an example, the work done in pumping a mixture of 15 per cent of sand and 85 per cent of water against a head of forty feet. We will assume, for the sake of calculation, that the pump has an eighteen-inch discharge, and that the velocity of flow is ten feet per second. Now, the weight of such a mixture of mud and water per cubic foot will be 85 per cent of that of a cubic foot of water at 62½ pounds equals 53.12 pounds, plus 15 per cent of that of a cubic foot of sand at 120 pounds equals 18 pounds, or a total of 71 pounds per cubic foot.

The discharge of the pump will be 1,056 cubic feet per minute, and the foot-pounds of work done will be that due to 1,056 cubic feet at 71 pounds per cubic foot, raised to a height of forty feet. This is equal to 2,999,040 foot-pounds per minute, or, say, ninety horse power. At 50 per cent efficiency, the horse power required to drive the pump will be 180. From this is can be deduced that an engine of 180 horse power, requiring, say, three and a half tons of coal per ten hours, will dredge and elevate about 350 cubic yards of solid material per hour, forty feet high, or 1,000 cubic yards per ton of coal.

A good dipper or grapple dredge, burning three and a half tons of coal per day, will dredge on an average 2,000 cubic yards per ten hours, or, say, 570 cubic yards per ton of coal. The dipper dredge, however, simply picks up the material and puts it down again—either into a scow, or on the bank, if it is near enough to reach. The hydraulic dredge, on the other hand, will deliver its output to a considerable distance, and spread it evenly over the surface. It is safe to say that transporting and spreading the material is at least worth as much as dredging it, so that, on this basis, the work of the hydraulic dredge has double the economic value of other types which do not transport and spread. These figures are, or course, merely approximate and will vary greatly, according to circumstances; but they will serve to illustrate the difference between the types.

A METHOD OF REDUCING THE COST OF ELECTRIC SUPPLY.

By Dr. Rasch.

(*Elektrotechnische Zeitschrift, 1895, p. 739; 2 figs.*)

The author refers to the unsatisfactory financial condition of various central stations for the supply of electric light, due to the very partial use of the generating plant. The highest ordinate of the December curve is a measure of the power of the plant, and upon it depend the cost of plant-administration, as well as salaries, wages and interest on capital.

There is a general desire to increase the load factor, but the charge of 3d. per kilowatt hour is still too high for motors of considerable size. Lower tariff is needed, and it is useless to require a guarantee that current for power shall not be used during the hours of the heaviest demand for light. The author considers it unfair to inquire the use to which the current is to be put; but suggests that the full rate should be charged for current used between 4 p. m. and 10 p. m. in winter, and between 8 p. m. and 10 p. m. in summer, while a considerably lower tariff should be fixed for all other hours.

He quotes Mr. Gisbert Kapp, who described the system in use at Ipswich, where each consumer has two meters, current passing through one or other according to the hour. In two other places the switching is effected by special clocks. The author considers

the following arrangement much simpler, as it depends upon the property of the watt hour meter whereby the readings are proportional to the potential at the ends of the volt-coil.

If the instrument is connected in the ordinary way, it gets the full potential on the line; but if a special weak current network be put in, the instruments can be controlled as desired. This network is single-pole only, and may be carried overhead like a telephone wire, or the test wires of the network may be employed.

In each house the volt-coil of the meter is connected on to the weak current lead at one end, and on to the ordinary network at the other end; on extended networks it may be necessary to insert secondary coils here and there to keep up the potential of the special network.

A special omnibus bar is provided upon the station switch-board for the volt meters, and an adjustable resistance is put in circuit.

If, for example, the ordinary potential of supply is 110 volts, and the price in the evening is 9d. per unit, and in the daytime 1.8d., then for the period covered by the latter tariff, the volt coils of all the meters must be worked at 22 volts by means of special leads.

The author then goes into details and explains that the system is applicable also to the three-wire system, and to systems with more wires still. He takes a tariff of 9.6d. for the evening and 1.8d. for the rest of the time, and works out numerous examples, by which he attempts to prove that the proposed method would tend to an increase in the load-factor while avoiding the production of a high peak in the curve where the power and light services overlapped.

ELECTRICITY STATIONS AS CENTERS FOR THE SUPPLY OF LIGHT AND POWER AND FOR RAILWAY WORKING.

By Dr. Martin Kallman.

(*Elektrotechnische Zeitschrift, 1895, p. 793, 6 figs.*)

This is a paper read by the author before the Elektrotechnischer Verein, in which he points out that a change has gradually been taking place in the public supply of electricity. Whereas at first the energy was used solely for the production of light, now the supply of power for motors and for railway working is becoming increasingly important. He takes statistics of seven large stations in towns having populations from 136,000 to 360,000, with an average of 219,000, and the statistics for Berlin, where the author is city electrician, are given separately.

The stations have been at work for periods varying from one year to three and one-half years, with an average of two and one-half years. Only one of the seven is worked by a private company, the others being municipal establishments. The stations in Berlin and Vienna are private concerns, and are also alluded to. All the seven stations use direct current, the three-wire system, and accu-

mulators, but in different degrees. Vienna uses principally alternate current.

Taking the average of all the seven stations, if the distributing capacity of the network be taken as a unit, the possible output of the plant is 61 per cent, the actual lamps connected 86 per cent, and the maximum output at any one time 38 per cent.

At the period of greatest output in December the plant was only loaded up to 65 per cent of its full power in the best station, and to 35 per cent in the worst, giving an average of 50 per cent. Taking an average for the whole year, that is to say, reckoning the whole time it would be possible for the plant to work, the load factor varies from 4.4 per cent to 7.1 per cent, or an average of 6 per cent of the lamps connected. It is, however, obvious that if light alone is supplied, a better load factor is difficult to obtain.

As regards revenue from a given network, the longest network connected to any one of the seven stations has 27.9 miles of house frontage, while the shortest has 5.58 miles. The demand on the network varies from 9 watts to 88 watts per yard of house frontage, with an average of 40.4 watts. A value is thus obtained which may be called the co-efficient of lighting density, but it is clear that it will tend to decrease as the distance of the area to be lighted from the business center of the city becomes greater. The number of houses connected varies from 232 to 592, with an average of 400, and the average number of lamps in use per house is forty-four. Reckoned per 1,000 inhabitants, the lamps vary from 48 to 160, with an average of 88.

The total cost of the stations under discussion varied from £65,000 to £125,000, with an average cost of £90,000, of which £50,000 was spent on generating plant, and £40,000 on distributing plant. This works out at 14d. per watt installed for generating plant, and 11.16d. per watt for distributing plant. The author gives curves of the daily and yearly consumption of current, and points out, that as an average, about 15 per cent of the lamps installed are in use on the days of greatest demand in the winter, while in the height of summer the average is 1.5 per cent. The yearly output of the stations under consideration varied from 270,000 to 470,000 Board of Trade units, with an average of 380,000 units. The sale price varies from 7.8d. per unit to 10.8d. per unit, while in Berlin it is about 6.84d. per unit, with certain discounts. Taking all discounts into account, the average price per unit is 7.56d. for all the stations, and an income of £15 to £17 10s. per annum can be reckoned per kilowatt installed. The author then goes into costs of production and gives a great number of figures. The averages appear to be per kilowatt hour: Coal, 0.54d. (it is found that 4.4 lbs. of coal produce one unit, of which 80 per cent is commercially available); oil, 0.09d.; salaries and wages, 1.08d.; interest on capital, 2.34d; and office expenses, 2.4d. to 3d.; making a total of about 6.6d. per unit. The author gives analyses of a number of other data concerning motor work, and shows some of the results diagramatically.

THE HAMBURG ELECTRICITY WORKS.

By Max Meyer.

(*Elektrotechnische Zeitschrift, 1896, p. 168.*)

The author refers to previous articles in which he has given information of a similar kind, and particularly cites Elektrotechnische Zeitschrift, 1894, p. 1, in which he arrived at the conclusion that most generating stations could make better incomes by the fuller use of their plant. He now gives details of a recent working period of the Hamburg Electricity Works, the first in Europe to supply electricity for both lighting and street railway work in such a way as to allow of general deductions being drawn. A complete description of the plant may be found in the Zeitschrift des Vereins deutscher Ingenieure, 1895, pp. 1509-1517. He therefore gives only a few particulars. For lighting there are two sets, each 500 h. p., and two accumulator batteries, each for 4,000 lamps; there are three similar sets for street car work, and a similar one of the same size as a reserve for either. This station cannot be enlarged, but a second one has been constructed by the electricity company, late Schuckert & Co., at a distance of 0.94 mile, and 5,000 h. p. are installed there. This will leave the first station free for lighting work only.

The street car company serves an area of about 30 square miles. The average total for the last month was 170 motor cars and 60 tow cars. The greatest length of line from the center is 6.82 miles. Certain results are given in the form of tables and these refer to the last nine months of 1895, and to the normal work of the plant, while that of certain reserve transformers for Sunday loads is not included. Table 1 shows that whereas in April, 1895, there were 892 customers, 25,330 glow lamps, 1,115 arc lamps, and 62 motors, making 1,717,850 watts on the circuit, these figures had risen in December, 1895, to 1,072, 31,861, 1,342, 130, and 2,213,800 respectively. Table 2 deals with commercial efficiency. This was in December, 1895, equal to 87.3 per cent for the accumulators, loss in leads 14.8 per cent, useful work compared with production 84.3 per cent, maximum daily output 25,632 kilowatt hours. Table 3 shows a load factor of 56 per cent when referred to a possible twenty-four hours full load; this is for December, and is obtained by the economical working of the five sets of 5,000 h. p. engines, and also by the high efficiency of the batteries. Table 4, which shows cost, is perhaps the most interesting. The results for December, 1895, per kilowatt delivered are as follows: Rent, taxes, insurance, etc., 0.0816d.; management, salaries and wages, 0.282d.; maintenance, repairs, etc., 0.004d.; fuel, 0.35d.; oil, waste and packing, 0.0384d.; total cost, 0.84d. This result is also obtained in November, and these are, of course, the most favorable figures, although they are closely followed by those for August, 0.876d., while April is the highest at 1.284d. In these calculations, receipts by the management for concessions, for reserve fund and interest are left out of consideration. As according to the police regulations

production of smoke is forbidden in the central station in the Poststrasse, expensive fuel has to be employed, and at present English coal costing 19s. 1d. per ton is used, and gives an evaporation of 9.5 lbs. of water. In the new station it will not be necessary to consume the smoke, so that the work will be carried on more economically. Part of the staff now employed at the first station will also serve for the management of the new station, and this will contain engines of 1,000 h. p. to 1,200 h. p. each, for which a steam consumption of 12.65 lbs. of steam per 1 h. p. hour is guaranteed. It is believed that the simple costs of production, as shown in Table 5, will descend to about 0.66d. or 0.72d. per kilowatt hour.

OBSERVATIONS UPON FILTERS OF VARIOUS KINDS.

By F. Breyer.

(*Gesundheits-Ingenieur, 1896, p. 90.*)

After very numerous experiments with many different kinds of filters, and among others upon the apparatus exhibited in the summer of 1895 at Paris, on the occasion of international competition, when thirty-five different filters were tested in the specially erected house on the Quai d'Austerlitz, the author arranges these appliances in three groups:

Group A. Consisting of those filters which rely mainly upon chemical action, and in which an effort is made to purify the water by means of preparations of iron, alum, or permanganate of potash.

Group B. Including sand filters, filled with coarse and fine sand, and animal or vegetable charcoal; and

Group C. Comprising hollow calcined cylinders of porcelain, or similar cells of artificially-moulded substances; likewise filters composed of porous plates of paper or asbestos, which furnished the principal types of the competing systems at Paris.

It is pointed out that when chemical substances are added to water in so diluted a state as to have no injurious action upon the human organism, their effect upon bacteria is extremely problematical, and on this account no further notice is taken of the apparatus included in group A. The chief advantage possessed by the filters in group B is the large area of their interstices which adapts them for dealing with water containing considerable proportions of sediment. While, however, from the point of view of the retention of the bacteria, filters of this kind leave much to be desired, it must be admitted that the apparatus included in group C, owing to the difficulty and costliness of the cleansing process, hitherto has given but a poor substitute for the sand filters and the appliances included in the second group. Reference is made to two filters exhibited by the author at the Paris competition, which gave excellent results in the outset. Owing, however, to the great number of bacteria, and the sticky, fatlike impurities present in the water, the pores of

the filter material became stopped up, and even the brushes employed to cleanse the surface of the filter became clogged, so that in lieu of removing the accumulations, they actually spread them over the surface as though they were a coat of paint. These evils induced the author to undertake the improvement of the action of his filter, which consists of compressed asbestos plates, and he employed a dust of very finely ground straw particles, which, after being subjected to a very simple treatment, have the same specific gravity as the fine asbestos powder. This preparation is added to the water, and is at once automatically spread over the surface of the filtering plates, and furnishes a protective layer which prevents the entry of the fine particles of slime, etc., into the pores of the filter. It can from time to time be readily washed off by a jet of water and speedily be renewed. This formation of a special external coating of fine particles automatically applied, renders the use of the brushes only necessary in very special cases, and reduces the cost of cleansing the filter to a minimum.

ELECTRIC POWER IN FACTORIES AND MILLS.

By F. B. Crocker, V. M. Benedict and A. F. Ormsbee.

(Transactions of American Institute of Electrical Engineers, 1895, p. 404.)

The authors point out that although the adoption of any system of power distribution depends primarily upon the cost, yet if the difference in cost between two systems is not very great, the question of convenience has great weight. They enumerate the following advantages of the use of electric motors instead of belts and shafting. (1) Facility for the use of traveling cranes, owing to increased head room; (2) ease of moving tools from place to place; (3) saving due to being able to run one tool by itself; (4) the absence of any absorption of power when the tool is stopped; (5) the avoidance of the drip of oil from overhead shafting; (6) ability to place tools at any point, irrespective of distance; (7) the tools need not be placed parallel to one another; (8) a wider range of speed is possible; (9) increased safety in case of overload, a fuse merely blowing instead of a belt flying off. The authors believe that in time electric driving will displace the older system.

After referring to what has been done full particulars are given of a number of determinations of the power taken by various tools in actual practice; these are summarized in the table.

The power was determined by measuring the current taken by the motor, readings being taken every few seconds, the interval between the readings depending upon the nature of the tool and the work it was doing. The pressure was 110 volts, and did not vary more than one or two per cent.

The authors call attention to the fact that the power taken by the several tools had been largely overestimated in the greater number of cases, the motor being only half loaded. As regards the extent to which shafting should be done away with, they are of opinion

that for large tools it is best to use a separate motor, while for small tools it is preferable to arrange them in groups, with a motor for each group.

The use of electric distribution of power in New England cotton mills has, it is stated, fairly begun, many having certain sections driven electrically, but none are as yet so entirely so worked. A short account is given of the plant at a dye works in Providence, R. I., where motors developing about 100 H. P. are at work, the most important being one driving a centrifugal pump taking 30 H. P.; also of that at a calico printing works at Pawtucket, R. I., the chief interest of which lies in the difficulty that had to be met in causing the motor to run at different speeds, and to keep running uniformly at any one of them under a variable load, a modification of the Ward-Leonard system of regulation being employed for this purpose; and at Baltic and Taftville, between which places there is a transmission of 500 kilowatts by means of alternating currents, one of the two motors driving 1,200 looms, taking about 155 H. P., and the other 500 looms, and the generators for the Norwich Electric Railway Company.

The authors are of opinion that, though in many cases the first cost of fitting up the necessary plant for electric driving is high, yet in the case of very long or scattered buildings, or those with many stories, it would be actually cheaper, one item of saving being the diminished strength required in ceilings or roofs. The loss of power in transmission is less with the electrical method, in spite of the double conversion, and very great saving is effected through there being no waste when the tool is stopped, the time of stoppage being at least 25 per cent of the nominal working hours, and as much as 50 to 75 per cent in the case of large or special tools. Great economy is effected when motors displace small separate engines scattered about a works. The greater convenience and facility for starting, stopping and speeding up lead to an increased output, and in case of the Pawtucket Calico Printing Works referred to, this is stated to have been as much as 25 per cent, while the quantity of inferior product produced was greatly diminished. As an instance of the great flexibility of the electric system, the authors mention a case in which a factory was almost wholly destroyed by fire, and yet within two days a few uninjured tools in a distant part of the building were got to work by means of motors.

The speed is varied in most cases by inserting a resistance in the armature circuit of the motor, which is shunt wound, but when the variation has to be between wide limits, a series motor, controlled by a resistance, as on electric railways, may be preferable. Other methods of regulation referred to are the Ward-Leonard and the "boost and retard" systems.

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SECRETARY,
NELSON L. LITTEN.

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ENTERTAINMENT COMMITTEE,

GEO. P. NICHOLS,
C. E. SCHAUFFLER,
T. L. CONDRON.

MEETINGS.

Annual Meeting: Tuesday after the 1st day of January.
Regular Meetings: 1st Wednesday of each month except January.
Board of Direction: The Tuesday preceding the first and third Wednesday of each month.

ABSTRACT OF MINUTES OF THE SOCIETY.

REGULAR MEETING—NOVEMBER 4, 1896.

A regular meeting of the Society (the 352nd) was held in its rooms, 1736-9 Monadnock Block, Chicago, at 8:00 o'clock, Wednesday evening, November 4, 1896.

President John F. Wallace in the chair, Nelson L. Litten, Secretary, and twenty four members and guests present. The minutes of the previous meeting were read and approved.

The Secretary reported for the Board of Direction as follows: At a meeting of the Board, November 2, 1896, the resignation of Max E. Schmidt was received and accepted to date December 31, 1896.

Applications for active membership from the following persons were received and referred to the membership committee: Bion J. Arnold, Richard C. Wagner, Wm. D. Sargent.

The Secretary was instructed to request of the proper officials of the various roads centering in Chicago tracings of their yards.

The discussion of the evening on Bedford Stone and Louisville Cement was then introduced by Mr. T. T. Johnston and largely participated in by the members present. At the close of the discussion the President read the following letter from Mr. H. A. Parker, assistant to the President of the Chicago, Rock Island and Pacific Railway Company, and stated that the invitation had been accepted and the Excursion Committee had made the necessary arrangements:

CHICAGO, Oct. 22, 1896.

MR. J. F. WALLACE, President Western Society of Civil Engineers,

Illinois Central R. R. General Offices, City.

Dear Sir:—It has been suggested that a visit to the double-track railroad and highway bridge now in process of erection by this Company and the United States Government over the Mississippi river, between Rock Island and Davenport, would be interesting to the members of your Society. I hereby, in behalf of the Chicago, Rock Island & Pacific Railway Company, tender your Society a special train from Chicago to Rock Island and return, and ask you to be the guests of this Company for the trip. The train will be furnished at such time and run upon such schedule as you may select. I would state, however, that by leaving Chicago at 8 a. m. your party could be returned to the city by 11 p. m. of the same day, and be given seven hours at Rock Island.

In addition to the bridge, the members of your Society would doubtless find much to interest them by an inspection of the United States Government arsenal at Rock Island, and for such a purpose I feel justified in assuring you the most cordial welcome from Colonel Buffington, the present Commander.

Awaiting your pleasure, I am,

Yours truly, H. A. PARKER, Ass't to President.

On motion the meeting adjourned.

MEETING—NOVEMBER 18, 1896.

The 353d meeting of the Society was called to order at 8:20 p m., November 18th, 1896, Vice-President Thos. T. Johnston in the chair, Nelson L. Litten, secretary, and 26 members and guests present.

The secretary reported for the Board of Direction as follows: November 17th, Franklin Pierce Dobson was declared elected to active membership; Mr. G. H. Bremner was reinstated as active member on recommendation and in compliance with the by-laws.

Applications for membership were received from Chas. Volney Kerr, John C. Quade, Tillman D. Lynch, Geo. M. Davidson, H. G. Hetzler, F. J. Johnson and G. W. Ashby.

Mr. James F. Lewis moved that a vote of thanks be given the Excursion Committee and our various hosts on the Rock Island Excursion, and that a committee be appointed to draft a formal letter of thanks. Unanimously carried.

Messrs. Geo. S. Morison, Hiero B. Herr and Alfred Noble were appointed as the committee.

The paper of the evening on "Street Railway Construction," by Edw Barrington, was read in part by the secretary. followed by discussion led by R. W. Hunt. participated in by a number of members.

On motion the meeting adjourned.

REGULAR MEETING—DECEMBER 2, 1896.

A regular meeting (the 354th) of the Society was held in its rooms, 1736-9 Monadnock Block. Wednesday evening, December 2nd, 1896, President John F. Wallace in the chair, Nelson L. Litten secretary, and 58 members and guests present.

The secretary reported for the Board of Direction as follows: Applications for membership were received from the following gentlemen: A. Z. Ross, W. G. Price, R. B. Owens, J. Walker Nelson L Litten R. D. Seymour, J C McMynn, Robt. L. Gifford, Geo. S. Griscom D. W. Church J. W. Gardner's time to qualify as an Associate was extended to December 31 1896

G. B. Springer was, on recommendation and compliance with the by-laws, reinstated. The resignation of E. L. Abbott was referred to the Membership Committee.

A committee consisting of Thos T. Johnston, E. Gerber and Alfred Noble was appointed to prepare amendments to the By-Laws.

An Auditing Committee, of which Hiero B Herr is chairman and Mr. John Lundie and H. N. Elmer are members, was appointed.

Current bills amounting to $408.51 were ordered paid.

Mr. Geo. S. Morison then presented, on behalf of the committee, draft of a letter of thanks to our hosts on the Rock Island Excursion, and a form of a letter which the committee recommended be engraved for permanent use.

Mr. Isham Randolph moved that the letter be approved and the recommendation adopted. Carried unanimously.

Mr. Thos. T. Johnston, chairman of Committee on Amendments to the By-Laws, submitted a report which was accepted and will be submitted to a vote by letter ballot.

The following committee was appointed to prepare suitable resolutions on the death of G. W. G. Ferris: Messrs. R. W. Hunt, S. G. Artingstall and W. M. Hughes.

The president announced that the annual meeting, by the new constitution, will be held on the first Tuesday after the first day of January.

The secretary then read an abstract of Mr Edw Barrington's paper on "Electric Traction" He also read written discussions prepared by the president and H. W. Parkhurst

Mr. H. M Brinkerhoff then followed with an extended discussion, participated in by Messrs. Geo. S. Morison, Summers, Lundie, Gerber, Coster, Bley, Jackson and others, until a late hour, when a motion prevailed to adjourn to Wednesday, December 9th, to continue the discussion. Prof. Jackson's paper was necessarily postponed to that date.

ADJOURNED MEETING—DECEMBER 9, 1896.

An adjourned meeting (the 355th) of the Society was held in its rooms Wednesday evening. December 9th, 1896 Vice-President Thos. T. Johnston in the chair, Nelson L Litten, secretary. and 58 members and guests present.

The discussion of "Electric Traction" was renewed with interest followed by Prof. D C. Jackson with his paper on "The Equipment of Manufacturing Establishments with Electric Motors and Electric Power Distribution."

By vote the subjects of the meeting were recommended for further consideration at the next meeting. December 23, 1896.

On motion the meeting adjourned.

MEETING—DECEMBER 23, 1896.

A regular meeting (the 356th) of the Society was called to order at 8:30 o'clock Wednesday evening, December 23d, 1896, Vice-President Thos. T. Johnston in the chair, Nelson L. Litten, secretary, and thirty members and guests present.

The subjects of Electric Traction and Power Distribution were called for by the chairman, but not obtaining a response, the paper of the evening on Natural Distortion of Rock in place as observed on the Chicago Drainage Canal was read by the author, Mr. Chas. L. Harrison, accompanied with drawings and illustrations of the remarkable movements of the rock. The paper was listened to with lively interest and was productive of thoughtful discussion. The paper with drawings and discussions will appear in the JOURNAL.

On motion the meeting adjourned.

At a meeting of the Board of Directors held December 22, 1896, the following applications for membership were received: Beverly L. Worden, Herbert E. Williams, Walter H. Baldwin, Harry Hurson Ross, Frederick E. Paradis, Frederick E. Turneaure.

The resignations of E. L. Abbott, L. Stumpf, W. R. Kellogg and P. Vedel were accepted.

NELSON L. LITTEN,
Adjourned. Secretary.

MEETING OF ALUMNI OF THE RENSSELAER POLYTECHNIC INSTITUTE.

The Alumni of the Rensselaer Polytechnic Institute of Troy, N. Y., will hold their annual mid-meeting in Chicago during the first week of February, 1897. An elaborate banquet at the Technical Club, or some equally appropriate place, will be one of the features of the occasion. There will also be excursions to the Drainage Canal, South Chicago Ship-Yards and other places of engineering interest.

The Rensselaer Polytechnic Institute was founded in 1824, by the late Hon. Stephen Van Rensselaer, as a *School of Theoretical and Practical Science.* In 1826 it received from the Legislature of the State of New York its act of incorporation, with those chartered powers and privileges usually granted to the higher educational institutions of this State.

In 1849 the Institute was reorganized upon the basis of a general Polytechnic Institute. Among the changes then introduced were a material enlargement of its course of study, with a proportionate increase of the time allotted to it, and a more elevated standard of requirements for the admission of candidates to the honors of graduation.

Since its foundation the Institute has sent forth a large number of graduates, who—as professors and teachers of the mathematical and physical sciences, as practical chemists and geologists, and as engineers in the various departments of constructive and topographical art,—have contributed to the increase and diffusion of science, as well as its applications to the business pursuits of life, with a success to which, it is believed, the Institute may refer with becoming confidence and just pride.

The Institute is located at Troy, New York, and its students are within easy access to engineering work of all kinds and in the midst of manufacturing plants of great diversity. The Burden Horse-shoe and Rolling Mills and Blast Furnaces; the Troy Steel and Iron Company's Furnaces, Bessemer Steel Works and Rail Mills; the Clinton Stove Works; the Gurley Mathematical and Engineering Instrument Factory and the Harmony Cotton Mills of Cohoes, all known throughout the country as pioneers in their specialties, are located within three miles of the Institute buildings.

Besides these, at Troy, Albany, West Troy, Green Island and Cohoes, and reached by street cars, are water works of every system, steel bridge works, wrought-iron pipe works, architectural iron works, electric light and railway plants of many types, the magnificent United States steel gun shops at Watervliet Arsenal, car shops and numberless forges, foundries, factories and machine shops engaged in an almost unequaled variety of production. Within an hour's ride are the Schenectady Locomotive Works and the extensive shops of the Edison Electric Company. Railroad and canal construction, architectural work and bridge building are illustrated both by usual and extraordinary structures. Coal and iron mines, marble and slate quarries are within visiting distance.

25TH ANNIVERSARY OF THE STEVENS INSTITUTE OF TECHNOLOGY.

A noteworthy event in the annals of technical education in the United States will be the forthcoming celebration of the 25th anniversary of the Stevens Institute of Technology, on the 18th and 19th of February next.

The festivities will consist of a banquet at the Hotel Waldorf, New York, to which representative engineers and technical educators throughout the country will be invited. On the following day the Institute will be open for inspection, and the methods of instruction, together with the apparatus in the various laboraorie s, will be explained.

Not the least interesting feature of the exhibition will be the collection, illustrating the work of the Alumni and consisting of machinery, apparatus, drawings, etc., representing the product of their activity during the 25 years.

The festivities also include a reception tendered to the faculty, graduates and undergraduates, by Mrs. E. A. Stevens, widow of the founder of the Institute, at Castle Point, Hoboken; a promenade, concert and dance in the evening will conclude the celebration.

The Stevens Institute of Technology was founded by the late Edwin A. Stevens, of Hoboken, N. J., and in 1870 the erection of a building was commenced by the trustees, Mrs. E. A. Stevens, Mr. S. Bayard Dod and Mr. W. W. Shippen. Dr. Henry Norton, at that time secretary of the Franklin Institute of Philadelphia, was tendered the presidency of the Institute, and gathered a faculty of eight members about him. To this number others have from time to time been added, as the work of the Institute increased, until at the present time the faculty includes twenty-two professors and instructors. The total number of student graduates is 675, and the number in attendance during recent years has been about 260 each year.

The Stevens Institute has always taken high rank among the institutions devoted to technical education in the United States, and its twenty-five years of successful effort is amply exemplified in the work accomplished by its graduates in all departments of mechanical and electrical engineering.

LIBRARY NOTES.

The Library Committee wishes to express thanks for donations to the library. Back numbers of periodicals are desirable for exchange and aid materially in completing valuable volumes for our files.

Since the issue of No. 5 of the Journal, we have received the following as gifts from the donors named:

W. W. Salmon—5 recent numbers of Deutscher Ingenieur.
Prof. D. C. Jackson—1 copy Alternating Currents and Machinery.
1 copy Text-Book on Electro-Magnetism and the Construction of Dynamos.
W. O. Seymour, R. R. Comm'r—44th Annual Report R. R. Comm'rs of Connecticut, 1896.
Secretary New York State Board of Health—12 vols. Report of State Board of Health of New York.

The Library and Reading rooms are open from 9 a.m. till 5.30 p.m. on weekdays, except Saturday until 3 p.m.

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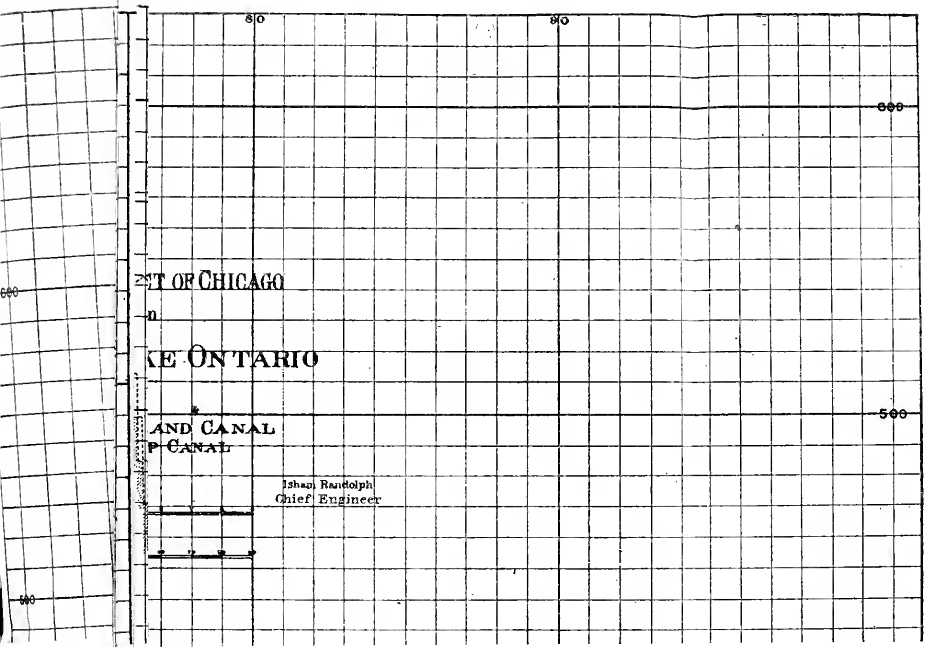
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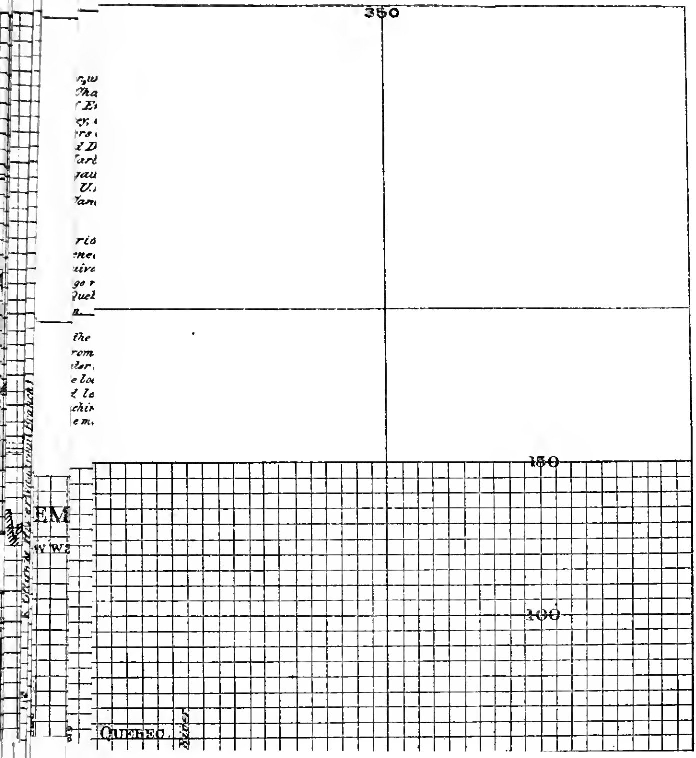
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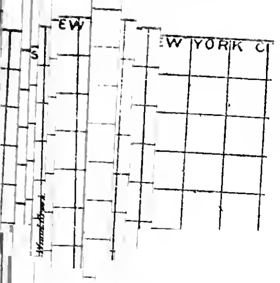
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